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THE MANUFACTURE AND DEVELOPMENT OF CARBORUNDUM AT NIAGARA FALLS.*

BY FRANCIS A. FITZGERALD.

The first carborundum furnace consisted of an iron bowl lined with carbon, and a carbon rod; a mixture of clay and carbon was introduced into the bowl and the rod placed in the mixture. A current sufficient to fuse the mixture, or at least to bring it to a very high temperature, was now passed through the furnace, the iron bowl and carbon rod serving as terminals or electrodes. When the current was cut off and the furnace had cooled down, it was opened, with the result that a few bright blue crystals were found surrounding the carbon rod.

The furnaces constructed after this first experiment approached more nearly in form the furnaces in use to-day. They were built of brick, their internal dimensions being

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10 inches in length, 4 inches in width and 4 inches in depth. The terminals were a pair of carbons, which could be moved longitudinally, thus permitting the distance between them to be altered at pleasure. These were essentially arc furnaces, that is to say, the idea was to form an arc between the terminals and to bring about the necessary chemical changes by the high temperature thus produced. Mr. Acheson soon found, however, that this method of working was not satisfactory, and he then set about constructing the incandescent furnace, which is the kind that is used to-day.

For this purpose he introduced into his furnaces a core consisting of granulated coke, which formed a continuous electrical connection between the carbon terminals. By adjusting the diameter of the core to the proper size, it was heated to a sufficiently high temperature, by the passage of the current, to convert the surrounding mixture into carborundum.

It was at first supposed that the crystals formed in the furnaces were a compound of aluminum and carbon, but Mr. Acheson soon saw that the amount and quality of the carborundum depended on the amount of silica present in the mixture. A good glass sand was, therefore, substituted for the clay in the mixture. It was also found that the addition of a little salt to the mixture facilitated the running of the furnaces. Some trouble was experienced from the gases formed during the running of a furnace, and to lessen this, sawdust was added to the mixture to render it porous, and allow the free escape of the gas. The output of these small furnaces amounted to about ¼ pound a day.

From this time forward the furnaces were gradually increased in size, until, in 1895, furnaces 9 feet long, 1 foot 11 inches wide and 1 foot 9 inches deep, with a core 8 feet long, were employed. The form of the core had also been changed, for while, in 1893, the section was rectangular, it was now circular, and measured about 9 inches in diameter. About 2,000 horse-power hours were expended on a furnace giving an output of about 300 pounds, 1 pound of carborundum thus requiring about 7 horse-power hours for its production.

We may now turn our attention to the works at Niagara Falls. The crude materials for the manufacture of carborundum, viz.: sand, coke, sawdust and salt, are received in the stock building. These are ready for immediate use, with the exception of the coke, which must be reduced to kernels of a certain size to be used as "core" and ground to a fine powder to be used in making the mixture or charge for the furnaces. To effect this, the coke is first passed through a grinder, which breaks it up into small pieces, and is then conveyed to the upper part of the building, where it is passed successively through two cylindrical screens. The first of these removes all particles of coke which are too small to form the core, while the second allows kernels of the requisite size to pass through its meshes and fall into the core bin, conveniently situated as regards the other constituents of the mixture. Below this bin are scales on which the sand, coke, sawdust and salt are weighed out in proper proportions, and then conveyed by an elevator to a mechanical mixer, from which the mixture, ready for use, is emptied into a bin. The arrangement of the machinery connected with all this work is such that it can be attended to with ease by two men.

The furnace room is built to accommodate ten furnaces, though at present there are but five. The furnaces are built of brick, and have the form of an oblong box, the internal dimensions being, approximately, 16 feet in length, 5 feet in width and 5 feet in depth. The ends are built up very solidly with a thickness of about 2 feet. In the center of either end are the terminals, consisting of sixty carbon rods 30 inches long and 3 inches in diameter. The outer ends of the carbons are enclosed in a square iron frame, to which is screwed a stout plate bored with sixty holes corresponding to the ends of the carbons. Through each of these holes is passed a short piece of $\frac{3}{8}$-inch copper rod, fitting tightly in a hole drilled in the carbon. Finally, all the free space between the inside of the plate and the ends of the carbons is tightly packed with graphite. Each plate is provided with four projections, to which the cables conveying the current may be bolted. These ends are the only

permanent parts of the furnace; the remainder, which we shall now consider, is built up every time the furnace is operated.

The side walls of the furnace are first built up to a height of about 4 feet. Pieces of sheet iron are then placed at a distance of about 4 inches from the inner ends of the carbon terminals in such a way as to keep the mixture from coming in contact with the latter. The mixture is then thrown into the furnace until it is rather more than half full. A semi-circular trench having a radius of 10½ inches, and extending from end to end of the furnace, is now formed, the bottom of the trench being a little above the level of the bottom row of carbons. Into this trench is introduced the core, which has been carefully weighed, so that the amount required to make the core of the right size is used. One of the furnaces at Niagara Falls requires about 1,100 pounds of "new core," that is to say, core which has come directly from the bins; or about 850 pounds of "old core," or core which has already been used in the furnace. The reason for this difference in weight will appear later. All the core having been emptied into the trench, the top is rounded off neatly by hand, so that when finished, we have a solid cylinder 21 inches in diameter and about 14 feet long, composed of small pieces of coke and extending from the sheet iron plates at either end of the furnace.

The next operation is to make the connections between the core and the terminals. This is done by packing finely ground coke into the spaces between the ends of the carbons and the pieces of sheet iron, after which the walls are built up to a height of about 5 feet, the pieces of sheet iron removed and more mixture thrown in and heaped up to a height of about 8 feet.

All that is required now to make carborundum is the electric current. The current as supplied from the Niagara Falls Power Company has an electromotive force or pressure of 2,200 volts, so that in order to use it in the furnaces it must be transformed to a lower voltage. This is brought about by a transformer, which, until recently, was the largest in the world, the largest now being that

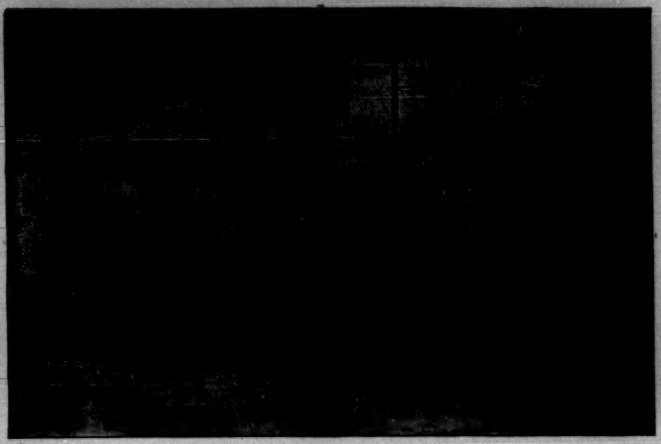

FIG. 1.—Transformer room.

FIG. 2.—Carborundum furnace ready for operation.

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used by the Niagara Falls Power Company, in transmitting power to Buffalo. The transformer at the Carborundum Works has a maximum capacity of 830 kilowatts, or about 1,100 horse-power, and transforms the 2,200-volt current into one of only 185 volts. Associated with the transformer is a regulator, by means of which the current from the former can be raised to 250, or lowered to 100 volts.

There is a loss of power in transforming the current to a lower voltage of about 4 per cent., so that with 1,000 horse-power no less than 40 electrical horse-power is transformed into heat. Obviously this would heat up the transformer and regulator to a temperature which would soon destroy them, so that some means must be employed to carry off this heat. Adjacent to the transformer and regulator are two oil tanks, one resting on the floor, and the other directly above and about 8 feet from the floor. The second oil tank contains two coils of pipe, through which water continually flows. A small pump, run by an electric motor, keeps the oil circulating through the regulator, transformer and upper oil tank, the lower one serving as a reservoir for the excess of oil. The oil flowing through the electrical apparatus carries off the heat from them, and is in turn cooled by the water in the coils of pipe. The current from the transformer and regulator is conveyed into the furnace-room by two copper conductors having a sectional area of 8 square inches each. Heavy cables connected with the large main conductors are bolted to the plates of the furnace which is ready for the current. The circuit is completed in the transformer-room by means of a water rheostat. This consists of a circular vessel made of iron, containing salt water, and a large iron plate which can be lowered into the solution. When the circuit is to be closed, the iron plate is lowered into the water until it rests in the bottom of the iron vessel. Similarly, in breaking the current, the plate is lifted off the bottom of the vessel and out of the water. The object of this arrangement is to avoid the dangers which attend other methods of breaking circuits which convey such large currents as that employed in this kind of work.

When the circuit has been completed, readings of the voltmeter and ammeter in the transformer-room are taken. If the furnace has been built with a new core the ampères or volume of the current is at first comparatively small; but if, on the other hand, an old core has been used, the current amounts to about 1,200 ampères. The reason of this is that the old core, having been already used in a furnace, has been heated to such a high temperature that all impurities have been driven off, and it, consequently, is a much better conductor than the new core. By means of the regulator the electromotive force or pressure of the current is now raised so as to overcome the resistance of the core, which is always comparatively great at first, even in the case of an old core, since, when carbon is cold, its resistance is much greater than when hot. In the case of a furnace having an old core, the resistance diminishes very rapidly, and at the end of about an hour the volume of the current has increased to the point where 746 kilowatts or 1,000 horse-power is being expended in heating the furnace. As the volume of the current continues to increase, the regulator is run back, reducing the electromotive force. Finally, the resistance of the core becomes constant, and very little more regulation is required. The phenomena attending the operation of a furnace containing new core are similar, but it takes a longer time for the resistance of the core to become sufficiently low to allow a 1,000 horse-power to be employed.

Readings of the voltmeter and ammeter are taken every quarter of an hour during the run of the furnace. From these the kilowatts are calculated and plotted on the power curve. From the area of the curve the total power used is calculated.

After the circuit has been closed in the transformer-room, no apparent change occurs in the furnace for about half an hour. Then a peculiar odor is perceived, due to escaping gases, and when a lighted match is held near the furnace walls the gas ignites with a slight explosion. When the current has been on for three or four hours, the side walls and top of the furnace are completely en-

veloped by the lambent blue flame of carbon monoxide gas, formed by the combination of the carbon of the coke with the oxygen of the sand. During the run of a single furnace 5½ tons of this gas are given off. At the end of four or five hours the top of the furnace begins to subside gradually, fissures form along the surface, from which pour out the yellow vapors of sodium. Occasionally, the mixture on the top of the furnace is not sufficiently porous to allow the rapid escape of the gases. The result is, that the latter accumulate until the pressure is so great that, at some weak point in the mixture above, a path is forced open and the gases rush out violently. This is termed "blowing" by the workmen, and the phenomena accom-

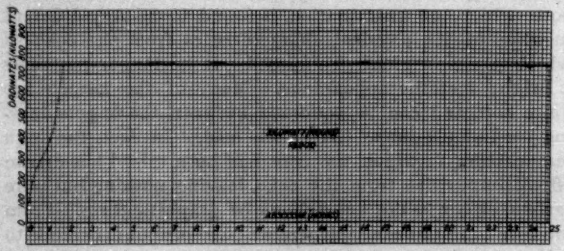

FIG. 3.—Power curve.

panying it are frequently as follows: A fissure suddenly forms at some point in the top of the furnace, and from this burning gases rush out with a loud, roaring sound. A miniature crater rapidly forms, from which white, hot cinders are thrown to a height of several feet, the issuing gases meanwhile burning with a dazzling yellow flame, dense white vapors soon filling the whole furnace room. In a bad case of this kind it is necessary to cut off the current from the furnaces and allow the latter to cool down somewhat. Then the mixture surrounding the crater is dug out to a depth of about 2 feet, exposing the "blow hole," which is removed, and the cavity formed filled up with fresh mixture. It is mainly for the purpose of avoiding this "blow-

ing" that the sawdust is put in the mixture, since the former, by making the mixture porous, allows the gases to escape freely.

At the end of about twenty-four hours the current is cut off from the furnace and it is allowed to cool for a few hours. Then the side walls are taken down and the unchanged mixture raked off the top of the furnace, until the outer crust of amorphous carborundum is reached. This crust is cut through with large steel bars, and can then be easily removed from the inner crust of amorphous carborundum. The inner crust is next removed with a spade and the crystalline carborundum exposed.

A cross-section of a carborundum furnace presents an interesting and beautiful appearance. In the center is the core, which, on examination, is found to be very different in some of its physical characteristics from the coke of which it was originally composed. It no longer possesses a bright metallic appearance. Many of the kernels are quite soft, and can be squeezed between the fingers, leaving on them a mark like black lead. In fact, the high temperature to which the core has been raised has driven off all impurities from the coke, leaving nothing but pure carbon, either in the amorphous or graphitic form. From the core radiate beautifully-colored carborundum crystals to a distance of 10 or 12 inches. A single furnace yields over 4,000 pounds of crystalline carborundum. Most of these crystals are not remarkable as regards their size, but in places where hollows have formed, large hexagonal crystals are found, sometimes measuring $\frac{1}{2}$ inch on a side. At the distance of 10 or 12 inches from the core the crystals suddenly cease, and instead, we find a thin layer of a light-green color, which is the inner crust of amorphous carborundum. Beyond this is the outer crust of amorphous carborundum, and this also ends abruptly in unchanged mixture. Other curious substances are sometimes produced in the furnaces; for example, silica, which has the appearance of spun glass. But, perhaps, the most interesting substance that is sometimes found is a curious layer next the core, of what Mr. Acheson has aptly termed the "car-

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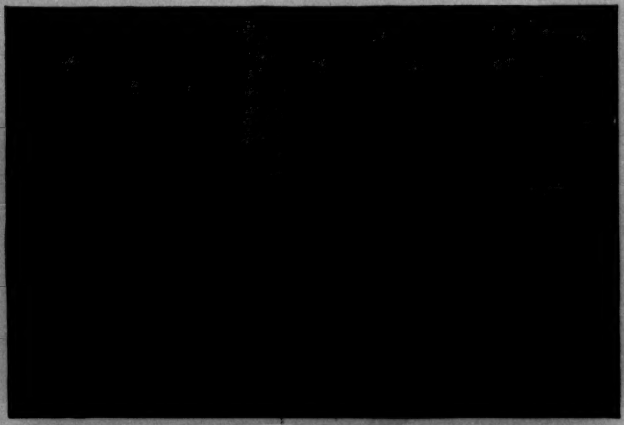

FIG. 4.—Furnace opened to show formation of carborundum around the core.

FIG. 5.—Cleaning the crude carborundum in the acid tanks.

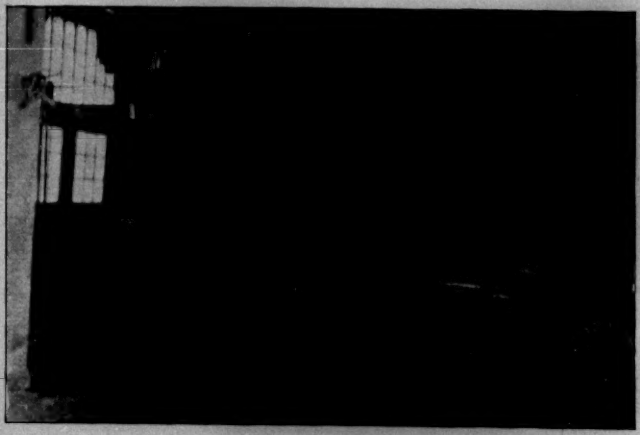

FIG. 6.—1,500-ton press used in making vitrified wheels.

FIG. 7.—View of interior of kiln for vitrifying wheels.

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bon skeleton of carborundum." On opening a furnace and cutting down to the core, a layer is found that appears at first sight to consist of very dull black carborundum crystals. On closer examination, however, it is found that though this material has the exact form of the carborundum crystals, it is nothing but pure carbon in the graphitic form.

This formation of the graphite skeleton of carborundum is interesting from another point of view, in that it suggests a new explanation of the formation of graphite from amorphous carbon. It has generally been supposed that when amorphous carbon is subjected to a very high temperature, like that of the electric arc, it is converted into graphite. Mr. Acheson, however, has pointed out that this does not properly explain what occurs; but that before the graphite has been formed, the carbon has entered into chemical combination with some other element, and that the compound thus produced is then decomposed, leaving behind carbon in the graphitic form. Attention has been called to the fact that after the furnace has been run, the core consists of pure carbon, either of the amorphous or graphitic form. Now if the production of graphite were simply a question of temperature, we might expect to see the whole core converted into graphite, instead of only part, that part being changed because of the presence of impurities in the coke, which have formed with the carbon chemical compounds, afterwards decomposed. It may be said that the whole core would be turned into graphite if heated to a high temperature for a sufficient time. This, however, is not the case, for even when the same core has been used in several furnaces, there is no appreciable increase in the amount of graphite formed after the first run.

At first sight it may seem strange that, so far as we know, carborundum does not occur in nature, even to a very small extent. Probably the explanation of this lies in the fact that the temperatures of formation and decomposition lie very close together. Other things equal, the temperature of the core in a carborundum furnace depends on the area of the cross-section, and since, in a given furnace, the

length of the core is constant, the increase or diminution of the weight of core used will cause a corresponding increase or diminution in the area of the cross-section. If a core 3½ per cent. less than the normal weight is used, it obviously makes a comparatively small difference in the sectional area and consequently in the temperature, yet this difference is sufficient to cause the decomposition of a large amount of carborundum next the core, the silicon being driven off in vapor and the graphite skeleton left behind. In a similar way a comparatively small increase in the amount of core used will decrease the amount of carborundum produced.

After the carborundum has been removed from the furnace it is taken to a crusher, which consists of a large iron pan, rotated in a horizontal plane by means of a vertical shaft. A horizontal shaft, carrying two heavy rollers, is attached to a collar surrounding the vertical shaft, thus permitting a free vertical motion of the rollers which rest in the pan. The latter, in revolving, causes the carborundum to pass under the rolls, which break the mass of crystals apart. From the crusher the carborundum is taken to large wooden tanks, where it is treated for several days with dilute sulphuric acid to remove impurities. It is then thoroughly washed, dried and graded. There are twenty grades of crystals, from No. 8. to No. 220, the numbers indicating the meshes to the linear inch of the screen through which the crystals have passed. The washings from the crystals pass through a series of tanks which serve to collect the fine powders, and from these are made the so-called "flours" and the hand-washed powders. The former are obtained by floating the ungraded powders in a stream of water flowing through a series of tanks, in which the powder settles. There are three grades of "flour," designated according to their fineness, F, FF and FFF. The hand-washed powders are obtained by stirring up a quantity of ungraded powder with water, allowing this to settle for a definite time—6 minutes, for example—and then pouring off of the supernatant liquid. The powder, which afterwards settles from this liquid is called 6-minute powder. In a similar way other hand-washed powders are made, 1-, 4-, 10- and 15-minute powders.

Having now followed the manufacture of carborundum from the preparation of the crude material for the mixture to the production of grains and powders in a commercial form, it may be of interest to consider its properties and uses.

Carborundum is apparently infusible; for after a certain temperature has been reached, decomposition commences, without fusion, and the crystals are broken up into carbon and silicon. It is quite insoluble in water or any acid. Its hardness lies somewhere between 9° and 10°, probably very close to 10°, which is the hardness of diamond. An attempt was made to obtain some idea of the relative hardness of diamond, corundum and carborundum by the following experiment:

A series of lines was scratched on a small plate of glass with each of the three materials, and the scratches examined with a microscope. The appearance of the lines made by the diamond and the carborundum crystal was indistinguishable; but that made with the piece of corundum was quite different, being rough, and not presenting the clean-cut outlines of the other scratches. This seems to show that carborundum is much nearer diamond than corundum in hardness, although it is not as tough. The specific gravity of carborundum is 3·23, which is less than that of emery, 1¼ pounds of the latter being equal in volume to 1 pound of the former. This is important for two reasons:

(1) It makes the relative cost of carborundum less than it appears at first sight; and

(2) A carborundum wheel is considerably lighter than an emery wheel of the same dimensions, which, of course, is a distinct advantage.

The most interesting application of carborundum as an abrasive is in the form of wheels. Taking what may be described as simple wheels, that is, those which are nothing more than circular discs having a hole in the center, the number which may be called for is very large. In the list of wheels given in the Carborundum Company's catalogue, we find that the diameters vary from 1 inch to 36 inches, the thicknesses from ¼ inch to 4 inches, the grits or sizes of

the crystals are more than twenty in number, and the grade scale, which is constructed to give the different degrees of hardness of the binding material contained in the wheels, consists of nineteen points. With these data a very conservative estimate of the number of different wheels which may be called for gives 80,000. Besides this there is an enormous number of dental wheels and wheels of special shapes, such as cylinders, cup wheels, roll-grinding wheels, special wheels for grinding machinery, saw-gummers, moulding wheels, etc. Besides the wheels there are many other forms in which carborundum is used, such as sticks, knife-sharpeners, hones, sharpening stones, gouge stones, slips, scythe stones, axe stones, cloth, paper, etc.

In the greater part of carborundum goods put on the market the vitrified bond is used. In making wheels or other goods in this way, the carborundum is mixed in certain proportions with kaolin and feldspar, and the mixture is then placed in a mould and pressed in a hydraulic press. The wheel, when removed from the mould, is placed on a support called a "bat," which is made of baked clay. The vitrification of the wheels is carried out in kilns similar to those used in making porcelain. The bats on which the wheels rest are placed in clay saggers, and then built up in columns until they reach the roof of the kiln. When the kiln is filled it is closed and fired, an operation occupying about seven days, and is then allowed to cool slowly. When the wheels are removed they have to be placed in lathes, trued up with dressers, or diamonds, and the hole bushed to the proper size. It is not easy to realize, at first, what a remarkable piece of work a carborundum wheel is. Who, looking at one of these wheels, measuring 36 inches in diameter and 4 inches in thickness, would think that the cutting material is produced by an expenditure of energy amounting to 1,250 horse-power hours?

Another bond, which has lately been employed with carborundum, is shellac. This is not of such wide application as the vitrified bond, but for work requiring very thin wheels or special forms, it gives very satisfactory results.

One of the first questions asked by a person who is alto-

gether unfamiliar with carborundum, is: "How much cheaper is carborundum than emery?" On being told that it is not cheaper, but from two to five times dearer than emery, he wishes to know why people should buy it under such circumstances. There are three reasons for this:

(1) As compared with emery, carborundum does more work:

(2) It does faster work:

(3) It does better work.

Another question often asked is, whether actual tests have been made for the specified purpose of comparing the relative value of carborundum and emery as abrasives. Such tests have been made, but they are very unsatisfactory. To make a really satisfactory test of this kind, it would be necessary to use a great many wheels of carborundum and emery, to make careful notes of the work done, the rate of doing work, and the finish of the work, and, from examination and comparison of these, to draw conclusions. Although no such test as this has actually been undertaken for the purpose of comparing carborundum and emery, yet data have been obtained under circumstances which fill all the requirements of a regular test. Among the large users of abrasives very careful observations are made of the amount of work, rate of work, and quality of work done by their emery, corundum or carborundum wheels, as the case may be. The results obtained from such observations as these are of far greater value than anything that could be done in the way of special tests. In the case of the latter there would always be subject for doubt as to whether the tests were carried out under proper working conditions. With the user of abrasives, however, there can be no doubt of this sort. He has been using emery or corundum for years, and finally he gets a carborundum wheel, which he tries, having before him the fact that it is far more expensive than an emery wheel, so we may feel perfectly sure that unless the superiority of carborundum is very decided, he will not waste time or money in making further experiments. A few of the results of observations made by men thoroughly experienced in the use of abrasives will then be of

interest, as giving us data from which we draw conclusions as to the relative values of carborundum and emery as abrasives.

Watchmakers have found that carborundum may be used in place of diamond, as it does the work equally well, and, of course, is much cheaper. Emery and corundum are quite unsuitable for this class of work.

In finishing the soles of shoes, garnet or emery, mounted on cloth or paper, is used. Numerous tests have been made by shoe manufacturers on the use of carborundum in this work, and they state that it does, approximately, six times the work of emery or garnet, does the work faster and puts on a better finish.

Extensive experiments have been made by a well-known plate-glass manufacturer, to find out whether carborundum can be used in that industry. In this manufacture the plate glass must be ground and polished. For this purpose a large mass of iron, weighing as much as half a ton, is passed over the plate of glass and grinds the surface, sand being used as the abrasive material. After the glass has been treated sufficiently with the sand, emery is used in its place, the final polishing being done with rouge. It requires about 20 tons of new sand to finish 1,000 square feet of glass. The experiments with carborundum show that 750 pounds of that material will do the work of about 20 tons of sand, and that $\frac{1}{2}$ a pound of carborundum will do the work of 12 pounds of emery. The experiments, however, were not entirely successful, for though a very small amount of carborundum was required to do the work, its extreme hardness made scratches on the glass plate. It is hoped, however, that this difficulty may be overcome.

In the manufacture of pottery and porcelain, blocks of carborundum are used for smoothing up the "biscuit ware," emery and corundum blocks having proved very unsatisfactory for this purpose.

In the manufacture of bath-tubs, rubbing blocks of emery have been used. In this class of work it is found that a man can do as much work with a carborundum block in one hour, as he could do with an emery block in one day.

Roll grinders record some very interesting observations of the work done by carborundum wheels. Thus it was found by one firm that emery wheels would grind about 65 rolls each before wearing down so much as to be useless; while carborundum wheels would grind 220 rolls each. Another roll grinder, who purchased a carborundum wheel, stated, when it ground 14 rolls, that it had "already beaten emery." When he next reported, he stated that the same wheel had ground 128 rolls, and was "good for 5 or 6 more." The difference in the number of rolls ground in these cases was due to the difference in their size.

An order was sent from a certain well-known car-wheel works for a carborundum wheel 18 inches in diameter and 2½ inches thick. A wheel of this size costs $15.38, while an emery wheel of the same size would cost $7.15. The agreement in this case, however, was that the Carborundum Company should receive 2 cents for every car-wheel ground. In order, then, to get the proper price for the wheel, it would have to grind 769 car-wheels. As a matter of fact, it ground 1,201, so $24.02 was paid for it.

Many more results obtained from carborundum wheels might be given, but those already mentioned are sufficient to show that these wheels are far superior to emery or corundum.

It is probable that, before long, a new field of usefulness will be opened to carborundum. In 1893, Dr. Wm. H. Wahl suggested to Mr. Acheson that carborundum might be used as a substitute for ferro-silicon. Since that time, however, Mr. Acheson has been too much occupied with the development of carborundum in the abrasive trade to make any experiments in the direction suggested by Dr. Wahl. It might have been expected, however, that before long this use for carborundum, so quickly recognized by Dr. Wahl, would be taken up by workers in the metallurgy of steel and iron. And such is the case, for experiments have been made with carborundum, not only by the metallurgists in the United States, but by those in England and Germany, with very promising results. The subject has been thoroughly treated by Mr. F. Luermann, of Germany, who finds that carbo-

rundum is soluble in molten steel, and suggests its use as a source of silicon in the manufacture of that material, if it can be obtained at a sufficiently low price. He estimates that carborundum which would be used in this way, in Germany alone, would amount to 2,444 tons a year.

Since Mr. Acheson discovered carborundum, in 1891, there has been other interesting work done on somewhat similar lines, notably that by Prof. Henri Moissan, of France, though, as yet, none of it has resulted in the formation of a new industry, like the manufacture of carborundum. However, in the future we may expect to see other wonderful results obtained from the electric furnace, in which temperatures can be reached that probably do not fall far short of that of the sun itself.

THE CYANIDE PROCESS FOR THE TREATMENT OF GOLD ORES.*

BY JOSEPH W. RICHARDS, PH.D., Member of the Institute.

Just three weeks ago to-day the news was flashed under the Atlantic Ocean that the High Court of the Transvaal had given a decision against the African Gold Recovery Company in its suit to compel payment of royalties for the use of the cyanide process, and had thus invalidated the MacArthur-Forrest patents in the Transvaal. This event was the sequel to a very interesting chapter in the history of gold mining.

In 1889, Herr Adolph Goerz, a well-known mining engineer, said, in the leading mining journal of Germany, that 50 per cent. of the gold mined in the Transvaal was going to waste. The common practice at that time was to crush and amalgamate the ore, the tailings from the amalgamation pans being in some cases concentrated, and the heavy concentrates treated by the Plattner chlorination process. It was a fact, then, and is true even to-day, that about 50 per

*A lecture delivered before the Franklin Institute, November 27, 1896.

cent. of the gold in the Transvaal ore is obtainable by amalgamation, 5 to 10 per cent. by chlorination of the concentrates, while 40 per cent. goes into the tailings from the concentrators. The difference between 1889 and 1896 is this: that whereas then no process was known for treating the tailings economically, and they were thrown away, now 90 per cent. of the gold in them is extracted by the cyanide process, at a handsome profit. Of the $40,000,000 return of gold from South Africa last year, at least $10,000,000 was won from tailings by the cyanide process, at a cost of (approximately) $5,000,000, leaving a clear gain to the gold interests of $5,000,000.

A process which, in five years after its introduction, can save to one country alone $5,000,000 a year, is certainly worthy of the respectful consideration, not only of the scientific world, but also of all who are interested in the progress of the industries.

The cyanide process is based on the fact that metallic gold is soluble in solutions of potassium cyanide. It is, indeed, a curious fact that *metallum rex*, which resists the attack of the strongest acids, only succumbing to that powerful mixture, *aqua regia*, should be quietly though energetically dissolved by an alkaline solution of a simple salt—potassium or sodium cyanide; yet the fact has been known since the beginning of the century.

(Experiment: Some gold leaf was floated on the surface of a solution of potassium cyanide in a watch-glass, when it was rapidly dissolved.)

On March 25, 1840, G. R. & H. Elkington, of Birmingham, England, patented the process of electrically depositing gold from its solution in potassium cyanide, using a gold anode to regenerate the solution. This is the process used even now to gild electrolytically, and the credit of its invention is said to be due to Dr. Wright, of Birmingham, for whom the process was patented by the Elkington Brothers.

The first scientist to study critically the conditions affecting the solubility of gold in cyanide solutions was Prince Pierre Bagration (*Bulletin de l'Academie Imperiale des Sciences de St. Petersburg*, 1843, t. 11, p. 136). He found that the gold

dissolved more quickly in a warmed solution, and that solutions of ferro-cyanides also dissolved gold, but not so energetically as the simple cyanides. He noticed also that the action of air facilitated the process of solution.

(Experiment: A fragment of gold leaf was placed in each of two vessels containing a 1 per cent. solution of potassium cyanide. Air was allowed to bubble through one, while the other was kept in agitation by stirring with a glass rod. In fifteen minutes the leaf in the first was entirely dissolved, while the other was apparently unattacked.)

L. Elsner (*Jahrbuch für Chemie*, 1844, p. 441) studied the question more closely, found that gold would not decompose cyanide solution without the presence of oxygen in some other form than as water, and that the reaction is:

$$2Au + 4KCy + O + H_2O = 2(AuCy.KCy) + 2KOH.$$

Theoretically, 1 part of potassium cyanide should dissolve $1\frac{1}{3}$ parts of gold, requiring $\frac{1}{25}$ part of oxygen.

The idea of making use of this solubility of gold in cyanide solution for the extraction of gold from its ores is said to have originated with Alexander Parkes and Dr. John Wright, who, in 1848, applied for a patent containing the following passages. (I quote from the *Engineering and Mining Journal* of December 16, 1895.)

The invention consists in separating gold or silver from their ores by means of cyanide of potassium, sodium or ammonium. * * * In order to facilitate the operation, the ore should be in a fine state of division. To every ton of ore, one-fourth to one-half of its weight of a 3 to 6 per cent. solution of potassium cyanide is used, heated in a suitable vessel to 150°–180° F. for one to three days. The solution is then filtered off, evaporated to dryness, and the residue fused in a crucible, by which the gold is collected to a button and the cyanide regained. The specifications conclude with: "I do not confine myself to the proportions above given, as more or less of the solvent must be used, according to the earthy or other impurities, nor do I confine myself to the above method of obtaining the gold from the solution."

This specification certainly contains the idea of the cyanide process, but there seems to be a doubt as to the genuineness of the reference. The *Engineering and Mining Journal* does not state the number of the patent; and while it is true that Parkes and Wright did take out patents in 1848, an examination of the full text of their patents from 1840 to 1860 has not revealed to me the above quotation, or anything approximating to it. I do not say that the patent may not have been applied for, but simply that I have not been able to find it by a diligent search.

At any rate, Parkes' proposed method never had any commercial application, and in the light of our present knowledge we can easily see why. (1) Too much cyanide would be lost by using so strong a solution, and keeping it hot one to three days. (2) The after treatment of the filtered liquid would be expensive and wasteful. The gold platers soon found out that metallic zinc precipitated gold from its cyanide solution in their plating baths, and the proper application of this observation was one of the necessities for rendering the cyanide process economical.

Subsequent patents were obtained as follows:

J. H. Rea, of Syracuse, N. Y. (U. S. P. 61,866, February 5, 1867). Use of potassium cyanide solution to dissolve the gold from the ore, and an electric current to decompose the solution and precipitate the gold.

Thomas C. Clark, of Oakland, Cal. (U. S. P. 229,586, July 6, 1880). The ore is roasted, and while red-hot dropped into a solution of common salt, ferro-cyanide of potassium and caustic soda, as a preparation to amalgamation.

Hiram W. Faucett, of St. Louis, Mo. (U. S. P. 236,424, January 11, 1881). The red-hot, roasted ore is dropped into a solution containing common salt, potassium nitrate, sodium cyanide, ferrous sulphate and copper sulphate. This also is intended merely as a preliminary to amalgamation, to dissolve any coating from the gold, and render it more susceptible to amalgamation.

John F. Sanders, of Ogden, Utah (U. S. P. 244,080, July 12, 1881). A solution of potassium cyanide and phosphoric acid is used in connection with amalgamation, to dissolve

the coating from the gold. This inventor plainly declares: "I am aware that cyanides have already been used in the extraction of gold."

J. W. Simpson, of Newark, N. J. (U. S. P. 323,222, July 28, 1885). The ore is powdered, agitated with solution of potassium cyanide and a little ammonium carbonate, filtered, a plate of zinc suspended in the solution to precipitate the gold, either scraping off the precipitated metal or dissolving away the excess of zinc by acid. The inventor declared he was aware that cyanide of potassium had been used, in connection with an electric current, for dissolving gold, and that zinc had been employed as a precipitant.

Regarding the last statement, it was known, as far back as 1851, that zinc would precipitate gold from solutions of gold in potassium cyanide, it being recommended as one of the agents by which gold could be precipitated from such solutions, and thrown down upon any article to be gilded, by the single-plate battery process.

None of the above-mentioned attempts were practically successful, while the process as exploited by the next following inventors was successful from the first.

The Cassel Gold Extraction Company was started in England in 1885, with a paid-up capital of $600,000, to operate some patented gold processes. These proving worthless, it purchased, in 1887, the cyanide process patents of MacArthur and Forrest. In 1889, its capital was increased to $750,000, all paid in; and in 1892 to $1,200,000, when the company began to pay dividends. The American patents were sold to the American Gold and Silver Extraction Company, of Denver, for $2,000,000 in shares; the South African patents to the African Gold Recovery Company for $100,000 in cash and $325,000 in shares; the Australian patents to the Australian Gold Recovery Company for $100,000 in cash and $265,000 in shares. After that, patent rights were sold in Mexico and other countries for cash and shares, and the parent company paid large dividends. The American Company has never collected much revenue, but the others mentioned have received large sums in royalties, probably between $1,000,000 and $2,000,000 having

been paid for the use of the process in the Transvaal alone. The process was first worked in 1888, at Ravenswood, in Australia; in 1889, at Barberton, and soon afterwards was introduced at Johannesburg.

Such being, in brief, the story of the phenomenal rise of the commercial cyanide process, connected almost exclusively with the names of MacArthur and the Forrest Brothers, of Glasgow, let us examine the actual patented basis on which their success rested. Their English patent, of August 10, 1888, specifies as follows: "The ore is powdered, treated with a very dilute solution of a cyanide salt, such dilute solution having a *selective action* such as to dissolve gold or silver in preference to the baser metals. The process is expedited by stirring the mixture of ore and solution. The solution is drawn off and treated in any known way, as with zinc, for recovering the gold and silver. For ordinary ores is used one-half their weight of a solution containing 0·2 to 0·8 per cent. cyanogen" (0·5 to 2 per cent. potassium cyanide).

In this patent the idea of novelty was based entirely on the use of the *very dilute* solution, as having a selective action and dissolving out the precious metals first. If exposure of the ore to 50 per cent. of its weight of such solution did not extract the gold satisfactorily, the solution was not made stronger (as that would entail greater loss of cyanide by dissolving the other metals present), but more of the solution was used.

This patent was supplemented by another one, claiming the use of zinc sponge or turnings in a box of special construction, forming a metallurgical filter (United States Patent 418,138, December 24, 1889), which has come into general use and will be described in detail further on. A companion patent (No. 418,137, December 24, 1889) describes the preliminary washing of the ore with an alkaline solution before subjecting it to the cyanide solution.

We have now examined the patented basis of the MacArthur-Forrest process, and the essential details may be summarized as:

(1) Use of a *very dilute* solution of cyanide.

(2) Precipitation by *spongy* or *thread-like* zinc.

(3) Preliminary alkaline wash, if necessary.

One is almost inclined to ask: "Is that all?" and I will reply that it is not. MacArthur and Forrest attacked the problem in a truly scientific manner. Not satisfied with some rule-of-thumb, hit-or-miss method of procedure, they investigated carefully, as chemists, every step in the series of operations involved. They subjected numerous ores to test, and, by making elaborate chemical analyses, determined exactly what constituents were detrimental to the cyanide solution, how their effects could be counteracted, and how, if possible, the impurities could be completely removed. They determined carefully the length of time required, the strength, and the amount of solution necessary and most economical for the treatment of various ores. They did not, of course, bring the process to perfection, but they put it on a solid basis of experimentally verified facts, and to this I, as a believer in scientific methods, ascribe the well-earned success which they have achieved.

It will now be interesting to turn our attention to a large-sized cyanide plant in full operation, and to describe the process as it is at present practised.

At the Metallic Extraction Company's works, at Florence, Col., the plant, at the beginning of 1896, handled 100 tons of rock per day, carrying $14 worth of gold per ton. The ore is broken first to walnut size, then to pea size, and finally ground to dust. It is then transferred to leaching tanks, 30 feet in diameter and 3 feet deep, each capable of holding 100 tons of dust. These tanks are of steel, having wooden bottoms, the latter being made double, as described in what follows: Strips of wood, 1 inch thick by 3 inches wide, are set up on edge promiscuously on the bottom of the tank, while a circular strip 3 inches high is fastened entirely around the bottom, 1 inch from the sides. The space between the strips is then filled with small pebbles to the level of the top of the strips. Over the whole is placed a circular piece of duck, cut about 6 inches larger in diameter than the tank. The canvas is pressed down into the 1-inch space between the circular ridge and the side of the

tank, a piece of 1-inch rope being pressed into this space to keep it down tight. The canvas is ordinary 10-ounce cotton duck, stitched like a sail. In the bottom of the tank, and closed by a valve, there is an outlet for solution.

The bottom having been arranged as above described, the vat is then filled with the ground ore, and 50 tons of 0·3 per cent. potassium cyanide solution is run in, just covering the surface of the ore. This remains one to three days, and is then drained off. The tank is then filled with a 0·1 per cent. solution, which is allowed to remain one day and is then also drained off. This is sometimes followed by a wash of 10 to 20 tons of pure water. The ore after this leaching contains 30 cents to 50 cents per ton.

The solution is run through four zinc boxes, each 18 feet long, 4 feet wide and 2 feet deep, and divided into ten compartments. Each compartment contains about 50 pounds of zinc turnings, and the box will precipitate the gold from the solution as fast as a 2-inch pipe will drain the vats, but it is not advisable to run it through more quickly than at one-fourth of that rate, lest the current should carry along with it, out of the precipitating tank, the finely divided gold.

During solution and precipitation, the loss of cyanide is approximately 1 pound per ton of ore treated, which costs 50 cents per pound.

The zinc boxes are cleaned up once a month. The turnings are vigorously shaken, to loosen the adherence of the fine gold, and the solution in the bottom of the tank is flushed out with the gold onto a canvas filter. The coarse particles of zinc are picked out and returned to the boxes; the gold slime is transferred to a lead-lined tank provided with a hood and is treated with sulphuric acid to dissolve out the zinc. If the slimes are well treated, the zinc is almost entirely removed, and the residue will contain over 50 per cent. of gold; if carelessly treated, they may contain 30 per cent. of zinc. After being washed and dried, they are melted down in crucibles with borax and soda, silica sand being added if zinc is present in any quantity. The bullion thus obtained is 800–950 fine. The cost of the process in the Transvaal may be summarized as follows:

	Per Ton of Ore.
Labor	$0.50
Potassium cyanide	.40
Zinc	.20
Coal, chemicals	.10
	$1.20

In Colorado, the cost of crushing and freight charges bring the total cost to from $3 to $5 per ton, making it profitable to treat ores carrying ½ ounce of gold or over. The Florence Works has been enlarged this year to four times its former capacity.

In South Africa three kinds of material are available for the cyanide treatment:

(1) Old tailings, the pyrites fully oxidized and washed out by the rains. They contain no acid, salts or slimes, and present no difficulties at all in the process.

(2) Recent tailings, partly decomposed, rich in ferrous and ferric salts and sulphuric acid. These present difficulties which are not insurmountable.

(3) Quite fresh tailings, entirely undecomposed. These are not yet perfectly treated, and need improvement in their handling.

At the Robinson Mine, the ore is first crushed and amalgamated; the tailings are put over Frue vanners, which separate them into concentrates and residues. The former are treated by chlorination, the latter are separated by "*spitz kasten*" into slimes and sands. The former are run away, the latter are put through the cyanide process. Practically, the only difference between the cyanide process at this works and that previously described, is that the precipitated gold from the zinc boxes is first roasted one or two hours at a dull-red heat, to oxidize the zinc and other base metals, and then melted down with borax and soda to bullion 600 to 800 fine.

Later improvements in the Transvaal have been directed towards doing away entirely with the chlorination process, and the saving of the slimes. The amalgamation residues are separated into four different grades by washing, and the cyanide process applied to each in a different manner, using

different strengths of solutions and different times of exposure. The slimes are mixed with lime, to render them more porous, and then leached. On these lines the extraction from the amalgamation residues has reached 90 per cent.

In the United States there are no large banks of tailings on hand to work, and the cyanide process has been applied simply to those ores to which it was best suited. These are particularly:

(1) The porous limestones of the Camp Floyd district, Utah. In these the gold is so very finely divided that no show of *color* can be obtained by washing in the miner's pan, and only about one-fourth of the gold can be extracted by amalgamation. The ore was practically unworkable by previous processes; but, from its porous, easy-leaching qualities and the fine state of division of the gold, it was the ideal ore for cyanide treatment, so that, to quote a recent expert report, "every mine, with reasonable ore bodies opened, equipped with a cyaniding plant, is a dividend payer." This ore needs only to be broken to about ½-inch lumps to be ready for treatment, about 85 per cent. of its gold being extracted at a total cost of $2 per ton. Five mills are already treating over 200 tons of ore per day, and three or four more are in process of erection. The cyanide process has literally created this mining district, and rendered workable one of the largest deposits of gold ore in America, a field having an area of 80 square miles and an average thickness of ore bed of 40 feet.

(2) The telluride ores of the Cripple Creek district. As is well known, these ores are very unsatisfactory for amalgamating, while roasting before amalgamation hardly mends matters. The cyanide process has been found very suitable for some classes of these telluride ores, and at Florence, Cripple Creek, and several other localities, is in successful operation. However, there are some kinds of Cripple Creek ore which do not work very satisfactorily, possibly because of selenium, but the exact reason is not yet quite clear. There are still unsolved problems for the cyanide process to conquer, and in solving which the chemist will find occupation for his highest skill.

Ores containing much copper usually consume large quantities of cyanide by the formation of copper cyanide, and are, therefore, unsuitable for the process. One per cent. of copper is the maximum which can usually be worked. Ores containing much lead sulphide, zinc sulphide or unoxidized iron pyrites, sometimes work satisfactorily and at other times not, the exact conditions for success having to be determined independently for each ore by careful experimenting; in some cases the ore cannot be worked at all by this process.

As just described, the cyanide process has been in use several years, with the result that others besides MacArthur and Forrest have devised improvements in its operation. The points on which improvement was most needed were:

(1) Increased speed of solution.

(2) Lower consumption of cyanide.

(3) A better method of precipitation than by zinc.

The mine owner would certainly have added to these a fourth very desirable improvement, viz.: freedom from paying the large royalties required, amounting to from 6 to 10 per cent. of the net output. This, as I mentioned in commencing, has been abrogated in the Transvaal.

Many inventors have attempted to increase the rate of solution of the gold by adding various chemicals to the solution. Molbenhaur uses ferrocyanide of potassium; Schering, potassium persulphate; Dupré, chromic acid; Mactear, hypochlorites; Crawford, cyanates; Peleton and Clerici, hydrogen peroxide and potassium permanganate; Kendall, sodium peroxide.

The principle of all these additions is to furnish the oxygen required for the reaction in a more available form than atmospheric oxygen. The only one of these that I can find proof of being in extensive use is Kendall's. About half a dozen plants in the West are using it, finding, on their particular ores, that solution can be hastened about 50 per cent., and thus the consumption of cyanide notably decreased. The reactions involved will serve as a type of most of the other methods, viz.:

$$Na_2O_2 + H_2O = 2NaOH + O;$$

therefore,

$$2Au + 4KCy + Na_2O_2 + 2H_2O = 2(AuCy \cdot KCy) + 2KOH + 2NaOH.$$

For lessening the consumption of cyanide, two expedients are resorted to:

(1) A preliminary treatment of the ore.

(2) The use of more dilute solutions.

It has become a settled practice to leach the ore first with pure water, if it should contain more than traces of soluble sulphates. However, some basic sulphates of iron insoluble in water can react on cyanide, so that if these are present, the preliminary wash is made with solution of caustic soda, or the ore is mixed with lime and leached. Sometimes careful roasting will decompose the soluble sulphates, forming oxides, and so rendering them harmless. The use of more and more dilute solutions has been the tendency in the Transvaal, where 0·05 per cent. solutions are considered fairly strong, and solutions as dilute as 0·01 per cent. are used. With this dilution, more of the solution is used to treat a ton of ore, say 1½ to 2 tons of solution, and less cyanide is lost than when using stronger solutions.

The use of more dilute solutions has emphasized the need of a better precipitant than zinc. When the latter is used, the theoretical reaction is:

$$2(AuCy \cdot KCy) + Zn = ZnCy_2 \cdot 2KCy \cdot + 2Au,$$

by which 1 part of zinc should precipitate 6 parts of gold. But in actual practice 8 parts of zinc are consumed per 1 part of gold in the best cases, while in the worst as much as 40 parts of zinc are used. This not only wastes zinc, but it wastes cyanide also, and it has been repeatedly observed that unless the solution contains a certain percentage of potassium cyanide before passing over the zinc, the precipitation of the gold is incomplete. The caustic potash formed in the solution of the gold (see Elsner's reaction), acts on the zinc to dissolve it, forming potassium zincate and setting free hydrogen, while the zincate reacts on the cyanide to form double cyanide of potassium and zinc. If

the solution is very dilute, zinc will not precipitate the gold satisfactorily. Molbenhaur tried to use aluminum, but it costs more than zinc, and soon becomes coated with alumina, thus stopping its reaction on the solution. Molloy used sodium amalgam, the object being to re-form sodium cyanide and amalgamate the gold. The difficulty of producing and using the amalgam and the expense of distilling it were the chief defects of this method. In fact, for strong cyanide solutions, nothing has been found more efficient than zinc, while for dilute solutions a method of electrical precipitation is fast working its way to the front, and I will close my lecture with a description of Siemen's and Halske's electrical process.

In 1887, Dr. Werner von Siemens put up a small cyanide plant in Germany to work the Siebenbürgen gold ores, using electrolysis to precipitate the gold from the solution. In 1888, he was still working at the process experimentally in Berlin. In 1894, it was first put in actual operation on a large scale at the Worcester plant in the Transvaal, and is now being used at the following Transvaal mines:

	Tons.
Worcester Works, monthly capacity	3,000
Metropolitan Mine, " "	5,000
May Consolidated Mine, monthly capacity	6,000
Crœsus " " "	6,000
Robinson " " "	8,000
Present " "	32,000

Charles Butters, the prominent Transvaal engineer, prophesies that 100,000 tons per month will be treated by the electrical method of precipitation in 1897.

The original apparatus used consisted of a large rectangular box containing cathodes of sheet lead and anodes of iron arranged alternately. The anode surface in a single box was about 7,000 square feet, and each box precipitated about 50 tons of solution per day. The iron is slowly attacked, and forms ferro-cyanide of potassium and thence Prussian blue, while the lead is coated with gold until it carries 10 to 20 per cent. of its weight of gold, and is then

removed, melted down and cupelled. The electric current used is, of necessity, very feeble, being only 0·06 ampère per square foot of depositing surface.

The present practice is to economize space by making the lead cathodes in the form of lead shavings enclosed in bags. At one of the present plants there are four precipitation boxes, each 30 feet long by 4 feet 9 inches wide by 3 feet deep. Each has 1,100 square feet of iron anode surface, and 110 cathodes of bags, containing each 5 to 10 pounds of lead shavings. The tanks are in series; a current of 200 ampères by 10 volts runs the four boxes. Each box will precipitate 50 tons of solution per day, containing 80 grains of gold per ton to 15 grains, a total deposit of $(80 - 15) \times 50 = 3{,}250$ grains $= 0{\cdot}464$ pound (average) gold per day (0·21 kilos). That this is an insignificant amount for the current passing (200 ampères), which should theoretically deposit 34·560 kilos in each box, is patent to the electrometallurgist, the yield being only 0·6 per cent.; but it must be remembered that the extraordinarily dilute solution used will not yield up its gold any faster, and that it must be electrolysed slowly to get any sort of correspondence between the power used and the gold obtained. There is still, however, plenty of room for improvement in both the zinc precipitation from the stronger solutions and the electrical precipitation from the weaker ones.

In conclusion, I would say that the cyanide process, while admirably adapted to some kinds of ores, is not at all to others; that it needs the best and most intelligent management, particularly on the chemical side, to render it successful; that there is still much room for improvement in its details; but that, given the right kind of ore and management, it is in most cases strikingly successful from both the metallurgical and economical points of view.

The Future of American Industries.*

By A. E. Outerbridge, Jr.

Gentlemen:—The letter which I recently received from Dr. Lindsay, requesting that I would speak to you on this occasion upon a subject which has occupied my thought, and with the practical side of which I have had daily contact—or at least cognizance—for several years past, states that you are "interested particularly in the kind and quality of labor employed in this country, and in the social significance of improved labor-saving machinery."

Two years ago I had the pleasure of addressing your predecessors in this class upon the subject of the "Educational Influence of Machinery,"† and one year ago on "Pending Problems for Wage Earners."‡

I purpose on this occasion to attempt to cast the horoscope of manufacturing industries in America for the opening of the new century. In so doing, I will venture to express some views which may not be considered entirely orthodox from the viewpoint of the old-time manufacturer, who adheres tenaciously to the economic teachings of the fathers of American industries, and fails to see or recognize changed conditions which are plainly apparent to others. No one disputes the self-evident fact that the food which is adapted to babes is not sufficiently sustaining for strong men; so also, when our manufacturing industries were young and weak, they needed, for their growth and development, fostering care and protection from the attacks of older and stronger rivals; but now, when they have outgrown their swaddling-clothes, and have, in some instances, become giants in stature, of herculean strength, they are

* An address to students in Economics and Sociology in the Wharton School of Finance, University of Pennsylvania (December 18, 1896), with some additions and omissions for this publication.

† *Engineering Magazine*, May, 1895.

‡ *Popular Science Monthly* and *Jour. Frank. Inst.*, May, 1896.

prepared to go forth and conquer in the impending peaceful battles for the commerce of the world. To do this they must break away from the leading-strings of the good mother government, and fight with the superior weapons they have forged for themselves while under her care and tutelage.

It is my conviction that many of our industries have now reached this period of adolescence, or even of full vigor, and are well armed and prepared to explore new lands and to conquer new territories.

Advance couriers have already been sent "to spy out the land," and, if I may venture to claim any degree of prescience of the future, resulting from careful study of past industrial conditions, I would say that, with the coming of the twentieth century, new and greatly enlarged fields of operation will be opened up by energetic pioneers in trade, who will not hesitate to hew out new pathways for themselves, even though many laggards may eventually follow after at their leisure and avail themselves of the advantages which have thus been gained by the pluck and toil of the pioneers.

Disclaiming any political significance or intent in the color of these introductory words, I desire to confine my remarks to a study of present industrial conditions and their indications, which are in some respects entirely unique, and, therefore, not yet fully comprehended by the majority of observers.

The ability to perceive, in advance of others, the gradual budding or unfolding of future events—that quality of mind or temperament which we commonly call foresight—is a rare one, and prophecies are always somewhat *risque*. I therefore ask you to recognize a difference between the value of the statistics and statements of fact here given, and of the predictions regarding the future based upon these facts. The former may be accepted without hesitation, the latter with due caution, remembering that there are not a few manufacturers who would to-day surround this country with a sort of Chinese wall for the purpose of excluding the possibility of entrance of rival manufactured products, and,

of course, thereby incidentally preventing export of our own manufactures to new markets.

This subject affords an interesting and never-ending game of battledore and shuttlecock for political wranglers, in which we are not particularly interested; we will, therefore, pass over this phase of the discussion altogether.

The existing condition and future prospects of manufacturing industries in this country present interesting problems for study to the student, the statesman, the manufacturer and the wage earner.

It is evident, even to a casual observer, that many industries which have proved profitable in the past have been over-stimulated; improved facilities for manufacturing have outstripped the capacity for home consumption.

Competition has lowered prices, wages have fallen, production has been curtailed (more especially during the past three years) and hardships have resulted therefrom.

Further curtailment of production, or else enlargement of markets, must prove the solution in the near future of this important economic problem, and the key to the situation may, perhaps, be found in the recent reports of the Bureau of Statistics in Washington.

These statistics show that exports of American manufactures are increasing year by year, thus proving that we are now successfully competing in the markets of the world with the manufactured products of cheaper labor in foreign countries.

Although complete returns for the year 1896 are not yet available, it is safe to estimate, from the figures furnished in the past eleven months, that the total exports of manufactures for the year will equal, if they do not exceed, $250,000,000. This will be about $50,000,000 more than in 1895, which figures were, in turn, about $25,000,000 more than those of 1894.

Subtracting from the total those items which do not involve elaborate mechanical processes (such as petroleum, copper ingots, etc.), it appears that about 70 per cent. of the value includes a great variety of manufactures in which skilled labor forms the largest element of cost.

These divisions include: Agricultural implements; sewing-machines; typesetters and typewriters; watches and clocks; boots and shoes; locomotives and other machinery; machine tools and hardware; electrical supplies and scientific apparatus.

It has heretofore been maintained—and, indeed, is still contended—by many manufacturers, that the relatively high wages paid to skilled labor in America, as compared with wages in European countries, preclude the possibility of successful competition; but facts are more convincing than theories.

Within the past few years several large manufacturers, thinking to avail themselves of cheaper labor abroad, have established branches of their works in different parts of Europe; the same equipment of labor-saving tools and, as far as possible, the same systems of management were employed.

The result in each case proved a surprise. American labor, though highly paid, is so much more efficient that it has been thus shown to be cheaper in the end than that of poorly paid operatives in Europe. Several specific instances of this kind might be given if space permitted. Exact imitations of American manufactured products, including machine tools, have been made in France, but they have cost more to produce there than the importation of the genuine articles cost.*

It has been contended that freight rates on all heavy manufactured articles would surely always prove a prohibitive handicap. Facts again disprove theories. Two years ago an Alabama furnace sent an experimental shipment of 250 tons of pig-iron to England. This was considered an "exceptional case," and was also pronounced a visionary project and derided as ridiculous in the extreme.

Within this brief period, says the *Manufacturer's Record*, the demonstration is complete.

"From that experimental 250-ton shipment this business has increased until now there is an actual scarcity of steamer

* *See Engineering Magazine*, January, 1897.

room to handle the business offered. Orders are being booked every week for large shipments to England and to Continental countries. It is difficult to rightly measure the influence of this trade upon the world's commercial interests."

From a recent statement by an officer of a leading furnace company, the foreign orders booked by that company alone amounted to about 40,000 tons, and inquiries under consideration between 30,000 and 40,000 tons. One of these, the same day on which this information was given, covering 5,000 tons, materialized into an order.

Pig-iron has already been shipped to Liverpool, Manchester, Rotterdam, Vienna, Genoa, Trieste, Yokohama and elsewhere abroad. These are facts not yet generally known.

Mr. John Fritz, in reviewing the history of the manufacture of pig iron during the past fifty years, at a recent meeting of the American Society of Mechanical Engineers, said that prior to 1840, when anthracite fuel was introduced in blast furnaces, the metal was nearly all made with charcoal, a good-sized furnace of that day producing 15 to 30 tons of pig iron per week. In a lecture on pig iron, which I delivered before the Franklin Institute in 1888,* I called attention to the fact that blast furnaces were then producing 1,000 tons of pig iron per week, and still larger output might be expected in the future.

The Carnegie Company is now building an extensive new plant at Duquesne, Pa., and furnace No. 1 is already in operation. During the past month (November) this furnace produced a daily average of 572 tons of standard Bessemer pig-iron, something hitherto unprecedented, and at the same time lowered the record with respect to proportion of fuel and cost per ton; 1,600 pounds of coke sufficed to smelt a ton of iron.

This company now controls ore beds of enormous extent on the famous Mesabi Range, in Minnesota, from which it obtains its low phosphorous iron ore at phenomenally low

* *Journal of the Franklin Institute*, March, 1888.

prices. It has taken from one mine alone—the Oliver—during the past year more than 800,000 tons, at a cost of less than 20 cents per ton, all charges included. The mining (so-called) consists in scooping out the hillside with steam-shovels and depositing the ore directly on the cars.

An idea of the capacity of this labor-saving machinery may be gained from the recent statement of Professor Winchell, that, in spite of certain unavoidable delays, "an output of 808,292 tons was made during the year with three shovels, one of which was idle about half the time."

The estimate of 20 cents per ton, here given, as cost of mining appears to be excessive, as Professor Winchell, who has itemized the factors going to make up the cost, states that the stripping charge per ton of ore, uncovered, does not usually exceed 6 or 7 cents per ton, and the cost of shovelling the ore out of its natural bed, after stripping, does not exceed 10 cents, and with a very large output may be less than half this amount.

Crude pig-iron stands near the bottom of the list of articles involving a high degree of skilled labor. American watches, on the other hand, head the list. Yet they are exported, in constantly increasing quantities, to all parts of the world.

Very recently, the American Consul at Bradford, England, reported as follows:

"One Bradford firm of jewellers alone has a stock of 20,000 Waltham watches. In addition, it has watches of the Elgin and other makes, and sells large numbers. American files, made by machinery, according to the testimony of Consul Meeker, compete with English hand-made files. He mentions one order, recently sent to this country, for 1,000 dozen, whereas an order for 200 dozen English files would be considered, ordinarily, as a large one.

"Go into any cutlery or hardware shop in Bradford," said Mr. Meeker, "and ask for shears, and you will be handed a pair bearing a Newark or Trenton, N. J., imprint. They are considered superior in every way, and one of the strange things about it is that they must be purchased through

Sheffield, which is supposed to be the rival of American cutlery manufacturers. These shears, a dealer said to me, are superior to all others, because they are 'sweet cutters.' The shears used by tailors and cutters are almost entirely of American make.

"Turbine water-wheels and printing-presses of American manufacture are also sold in Bradford."

The export of machine-made boots and shoes is rapidly growing, and has indeed already assumed large proportions.

Within a few years past, great improvements have been made in the shoemaking machinery and in the product, accompanied by an equally noticeable reduction in cost.

Few persons are aware of the present extent of this business, which has grown up from very small beginnings. Statistics show that, in the census year of 1890, no less than 179,500,000 pairs of boots and shoes were made in factories in this country, by 194,000 operatives, an average of nearly 1,000 pairs per annum for each employee, and an average of nearly 3 pairs of shoes for every inhabitant.

A single factory, employing 233 hands (chiefly girls), turned out 2,100 pairs of women's shoes a day.

The best qualities of machine-made shoes are now fully equal to the best hand-made shoes, and are produced at one-third the cost; this accounts for their favorable reception in a number of new markets, in spite of former prejudices and of occasional misrepresentations of rivals, who naturally fear loss of business.

Seven thousand tons of steel rails, besides enormous quantities of other railroad material, are now being made in Pittsburgh for Japan, and large orders have, it is said, been booked for China.

A complete locomotive-manufacturing plant was recently shipped from Philadelphia to Russia, and railroad machinery is now on its way from this port to Australia.

A multitude of similar illustrations could be given, but these will serve as straws to show the direction in which the "trade-winds" are now blowing, and it only remains for American enterprise to take advantage of the opportunities which favorable circumstances offer to enter upon a new era of industrial prosperity.

The secret of success in these tentative experiments is to be found in the wonderful advances which have been made in labor-saving machinery, supervised by intelligent, highly paid operatives, whereby the productive capacity of each employee is enormously increased and the cost per unit of product correspondingly reduced.

The possibilities of reduction in cost of manufacture of any given articles are not always appreciated first by those who are most familiar with the routine methods. New departures are apt to emanate from those who approach the problem from a new standpoint, unbiased by old traditions.

A striking illustration of rapid changes in methods, and concomitant great reduction in cost of manufacture, is furnished in the recent history of the evolution of the incandescent electric lamp.

In 1880, I visited Edison's laboratory at Menlo Park, to inspect his new system of incandescent electric lighting.* I was then much impressed with the novel methods of making, in considerable numbers, the delicate lamps and filaments, and regarded them as marvels of mechanical ingenuity.

I understood, at that time, that Mr. Edison had succeeded by his methods in reducing the cost of manufacture of the little lamps one-half—*i. e.*, from about $3 to $1.50 each.

To-day, lamps, far superior to the earlier forms made in 1880, are sold in large lots at less than 20 cents each! A single factory of the General Electric Company turns out 6,000,000 a year, and the output of all the factories combined is about 20,000,000 lamps per year.

It is interesting, in view of the present low cost of the lamps, to know that the carbon filament is estimated to be, weight for weight, the most valuable substance known.

Filaments for the ordinary 16-candle-power lamps are worth $10 a thousand, and 14,000 are required to weigh 1 pound.

The filaments in the tiny bulb lamps used for surgical and dental purposes are very much smaller, and are three

* For description, see *Journal of the Franklin Institute*, March, 1880.

times more valuable if estimated by weight, or more than $400,000 per pound.

Formerly, it was customary to estimate approximately the cost of a locomotive at $1,000 per ton weight. Thus, an engine weighing 40,000 pounds would cost about $20,000. To-day, a first-class locomotive, weighing about 130,000 pounds, costs about $8,000, or less than 6¼ cents per pound. Labor-saving machinery and "piece-work" systems of pay are largely accountable for these results.

The Pennsylvania Railroad has made an interesting, almost startling, discovery of the value of the piece-work system of remuneration in its shops at Altoona, as compared with the "days'-work" plan formerly in vogue.

An elaborate description of these methods, and of the results attained, may be found in the current number (December) of *The American Engineer, Car Builder and Railroad Journal.*

It is stated that, before the introduction of the new system, fifty new locomotives per annum represented the capacity of the shops. Since that change, the output—with substantially the same tools and appliances—has doubled. "The cost of days' work in the erecting shops of what are known as Class I engines was $290. The same amount of work, on engines of the same general class, but about 15 tons heavier, now costs $95.75, and is done in one-half the time. * * * By days' work it took three days to build a box car. This work is now done in fifteen hours.

"The pipe work on a locomotive formerly cost $137, and now costs $32."

Figures are given, showing that, while the output has been doubled and cost of labor reduced one-half, wages have been raised more than 25 per cent. under the new system.

The value of this change may be better appreciated when it is stated that the cost of equipment on the Pennsylvania Railroad last year was $9,500,000, of which about $4,750,000 was labor.

In conclusion, I may repeat what I have said on a former occasion that the introduction of labor-saving

machinery has enormously increased the output for each workman, and this introduces a new element into the ethics of the question of wages, and also into the practical question of cost. If it can be shown that a skilled workman, at a slight increase of labor and attention, can enormously increase the output of a machine, he should be encouraged to make the effort by an increase of pay.

An increase of output must logically and necessarily involve a fair increase of wages, and, in a properly conducted business, this increase of wages, following increased output, must mean increased profit.

This is a profit-sharing scheme to which there can be no practical objection.

While the brief statements here given are intended merely as indications of the present and prospective condition of manufacturing industries in America, they seem to point clearly to the encouraging fact that this country is about to enter upon an era of industrial prosperity through growing expansion of its commerce and manufactures.

COMPRESSED AIR FOR CITY AND SUBURBAN TRACTION.*

By Herman Haupt.

[*Concluded from p. 26.*]

RESULTS OF TESTS.

Compressed air motors have long since passed the experimental stage. They have been running for two years at Rome, N. Y., and through the kindness of the officials of the New York Central Railroad have been repeatedly allowed to run on the main track, where a speed has been attained of 30 miles per hour with wheels of only 26 inches diameter.

It should be obvious to every person of intelligence that

* Read by title, November 18, 1896.

a compressed air motor can be planned to fulfil any conditions, or perform any service, within the capacity of a steam locomotive. Speed requires large wheels, length of run large storage. High grades and heavy trains require large cylinders. The motor must be adapted to its work and fulfil the conditions of its service.

Tests have been made repeatedly by engineers and experts from all parts of the country, all of whom, without exception, have made favorable reports. One of these tests, made in the presence of the writer and of Captain Fiebeger, of the U. S. Engineers, February 18, 1895, gave the following results:

Starting with a pressure of 1,900 pounds in motor, and temperature of 291° in the water of the reheating tank, the first six runs of 4,800 feet were made on an average of 221½ cubic feet of free air per mile.

The next six runs of 4,800 feet, temperature 252°, required an average of 339 cubic feet per mile.

The water in the tank was then reheated, by attaching a steam hose, to 302°, when the next run was made on an average of 208½ cubic feet per mile, from which the required quantity of air increased as the water became colder to 377 cubic feet per mile. After the tenth run, the water was again reheated, and the quantity of air fell per mile to 247 cubic feet, and then increased to the fifteenth and last run, when the temperature was 247° and the quantity of air per mile 521 cubic feet.

The average expenditure of air during the whole test was 308 cubic feet per mile. When the water was emptied from the tank and cold air used, the consumption was 661 cubic feet per mile on the same track.

This motor was calculated to run a maximum distance of 12 miles, with one charge of air, but as the reservoir capacity was 35 cubic feet, under 136 atmospheres, the cubic contents of free air was 5,760 cubic feet, which, divided by 308, gives 18·7 miles as the possible run if all the air could have been used. Allowing 2·7 miles as a reserve, there would still have remained an effective run of 16 miles. There can be but little doubt that by an efficient system

of reheating, whereby the temperature could be maintained at 300°, a greater efficiency could be secured.

It is unnecessary to give the results of other tests; they have been quite numerous, and by different experts, and confirm substantially the conclusion above stated.

The motors now running daily on the One-hundred-and-twenty-fifth Street railway in New York make 17 miles with one charge of air. The reservoir capacity, 50 cubic feet.

Why is compressed air cheaper, both in installation and in operation, than any other system of traction for city and suburban service?

It requires less power at the power station for a given service, and this means less cost for engine plant and a perpetual saving in coal consumption.

A comparison with the trolley must be based on similar conditions, and as the recognized maximum distance of transmission of electrical power under 500 volts is 5 miles, a line of 5 miles, double track, with two-minute headway, will be assumed as a basis of comparison, average speed 10 miles per hour, and 30 motors on line.

Electrical motors are usually supplied with two 25 horse-power motors, making 50 horse-power each, but as the full power is required only in overcoming the maximum resistances, the power provided at the power station is usually calculated upon a basis of transmission of 25 horse-power for each motor.

This transmission involves many losses, and only a comparatively small portion can be actually utilized at the rail.

In the *Engineering News* of October 17, 1895, p. 256, is found the following estimate, the indicated power of the engine at the power-house being taken at 100:

	Per Cent.		*Per Cent.*
Engine friction	8	Remains	92·0
Belting and shaft	10	"	82·5
Dynamos	8	"	76·2
Transformers at power station	7	"	70·9
Line to sub-station	12	"	62·4
Transformers at sub-station	7	"	51·8
Rotary converter	16	"	48·8
Railway circuit	10	"	43·8
Car motor	15	"	37·2

This estimate gives only 37·2 per cent. of the indicated power at the station as effective at the rail; but as other estimates claim a higher efficiency, it will be assumed as 50 per cent.

The thirty motors on the track will therefore require 1,500 horse-power as the prime mover at power-house.

Thirty air motors, with a run of 10 miles, will require 4,000 cubic feet of free air, or 2,000 cubic feet per minute, compressed to 2,000 pounds, and the horse-power at the station will be 900, or 600 less than with electricity, and there is no loss in transmission.

COMPARATIVE COST OF MOTORS.

It is usually claimed that the cost of compressed air motors is considerably greater than the cost of electrical motors for equal service.

This is a mistake; the comparison must be made under like conditions. The compressed air motor carries its power with it. The electric motor takes it from the line. A fair and just comparison requires that the cost of plant to furnish power on the line should be included or omitted in both cases.

Omitting the reservoirs, estimates for the air motors have been brought below the electric motors, notwithstanding the low price of the latter, due to active competition; but allowing the cost to be the same in both systems, a comparison will be made between the reservoirs for thirty motors and the line construction required to furnish the electrical power for an equal number.

The thirty air motors will require 110,000 pounds of reservoir, costing about $15,000; per motor, $500.

The cost of line work for 5 miles of double track, with thirty motors, will be $26,000; per motor, $866.

POWER PLANT.

Another great saving is effected in the cost of power plant. It is usual in electrical estimates to allow $80 per horse-power at the power station, exclusive of land and

buildings for engines, boilers, shafting, belts, dynamos and other apparatus.

The cost of 1,500 horse-power, at $80 per horse-power, would be $120,000.

Compressed air requires no dynamos, belting or shafting. Steam from simple boilers is piped directly to the compressor, and it would be an excessive estimate to assume that the cost is one-half that of electricity, or $60,000.

SAVING IN TRACK.

The track for air motors requires no girder rails or electric binding or welding. A simple cross-tie track, as is used for ordinary locomotives, is sufficient. The reason for this is that the weight on the air motor is spring-supported, and on the electric motor a much heavier load is rigidly attached to the axle. From a table furnished to the writer by Franklin L. Pope, it appears that the effect of a blow of 1 ton from a wheel passing over an obstruction $\frac{1}{8}$ inch in height, at a speed of 20 miles per hour, is twenty-seven times as great when the weight is rigidly attached as when it is relieved by springs.

The saving with compressed air increases with the magnitude of the plant. Without encumbering this paper with detailed estimates, it is proper to state that the writer prepared a close estimate of the relative cost of electricity and compressed air for a transmission of 5 miles from the power station on an elevated railroad, such as the Third Avenue Railroad, in New York, with trains running at one-minute intervals. The estimate for electricity was submitted to a prominent electrical engineer and pronounced correct. The cost was more than double that of the compressed air installation. In fact, the return electrical current could not be transmitted in the ordinary way by rail, but would require some special arrangement. The attempt to reduce the cost of copper by increasing the voltage of transmission is attended with great increase of risk to life.

A system that may prove satisfactory on a small scale and with a limited volume of business may result in failure

if extended beyond certain limits. President Vreeland, of the Metropolitan system, in New York, in an interview recently published in the *Herald*, pronounced the underground electric system in Lenox Avenue unsuited for a line with a heavy business. It required sometimes from two to four days to locate a defect, which, when found, could be remedied in ten minutes.

In selecting any system for adoption, the sensible course is always to get estimates in detail from competent and unbiassed engineers, covering every point of installation and of operation, and then find responsible contractors to guarantee the work within the limits of the estimates.

COST OF OPERATION.

It has been shown that the cost of installation of a compressed air system is much less than that of the ordinary cheap trolley with wooden poles. If it can be shown also that the operation is more economical, then there can be no question as to its superiority in this particular over the cable, underground electric and other systems, all of which are much more expensive than the trolley.

The following is the latest revised estimate of an engineer long connected with electric companies and familiar with all details of operation, but at present engaged in the introduction of compressed air installations:

MOTIVE POWER PER CAR MILE (run 120 miles per day).

	Cents.
Anthracite coal for compressor plant	0·870
Anthracite coal for reheating	0·110
Water, boiler-feed, etc.	0·022
Oil, waste, etc.	0·024
Removal of ashes, etc.	0·014
Operating labor	0·615
Maintenance of power plant, etc.	0·163
Maintenance of motors, etc.	0·280
Interest and general expenses	1·760
	3·858

TRANSPORTATION.

	Cents.
Maintenance of cars, trucks, buildings	1·619
Motormen, conductors, etc.	6·133
General expenses, interest, etc.	1··55
	12·765

Electricity, similar items included, costs	16·268
Difference, 27 per cent.	3·503

SOME INTERESTING FACTS.

By reheating the air required for the operation of a motor, the efficiency may be so much increased that more power may be utilized in the motor cylinders than was expended at the power station in the compression of the air.

This statement has often elicited a smile of incredulity as it seems to be in violation of the law of the conservation of energy, but it is susceptible of a simple explanation.

Take the horse-power at the compressor, say 1,400 horse-power to compress 3,600 cubic feet of free air per minute to 2,000 pounds, the foot-pounds in 10 hours would amount to 5,544,000,000.

The number of motors that this amount of air would supply is 120, assuming cylinders 6 x 14 inches; wheels, 26 inches in diameter; speed, 6 miles per hour; consumption of free air, 300 cubic feet per mile; pressure, 140 pounds per square inch, cut off at one-tenth stroke; mean pressure, 46·2 pounds per square inch. These conditions would give 6,802,272,000 foot-pounds of work in the cylinder of the motors, or 22 per cent. more than the foot-pounds of power expended at the compressor.

How can this be explained? Simply by the reheating of the air, which increases its volume and by the steam which accompanies it and adds greatly to the effect.

But if air is reheated and steam used as an auxiliary to increase the effect, will not the expense of reheating fully offset any advantages thereby secured?

COST OF REHEATING.

From tests made in 1879, it was found that for 50 cubic feet of free air passed through the reheater, 1 pound of water, in the form of steam, was absorbed; 300 cubic feet of air would, therefore, absorb 6 pounds of water. Under a pressure of 140 pounds, the temperature would be 353°, or for effective pressure of 140 pounds, the absolute pressure

would be 160 pounds and temperature 364°. The latent heat at this temperature is 858°.

The heat units required to raise 6 pounds water from 60° to 364°, including the latent heat, will be $1{,}162 \times 6 = 6{,}972$ units. To raise the temperature of 300 cubic feet of air 23 pounds, from 60° to 364°, specific heat of air being 0·24, will be $304 \times 23 \times 0{\cdot}24 = 1{\cdot}678$ units.

The total units required for reheating for 1 mile will, therefore, be $6{,}972 + 1{,}678 = 8{,}650$ units, which would be supplied by four-fifths of 1 pound of coal, at a cost of $1\frac{1}{8}$ mills.

This coincides very nearly with Mr. Hardie's experience, that the cost of reheating was about one-eighth the cost of compression.

EXPANSION IN REHEATING.

Fifty cubic feet of dry air carries over 1 pound water, which in steam, at atmospheric tension, gives 52 per cent.

Air at 60° F., heated to 364°, will expand in proportion of $461 + 60$ to $461 + 364$, or 521 to 825, which is 58 per cent. Total increase of volume, 110 per cent. Hence, 300 cubic feet will become 633 cubic feet. Without reheating the water on the trip, the Hardie motor, at Rome, consumed 331 cubic feet per mile, 110 per cent. of which would be 695 cubic feet. The actual consumption of dry air was 661 cubic feet.

INFLUENCE OF SPEED IN CONSUMPTION OF AIR.

A very general, but very erroneous, impression appears to exist in regard to the increased consumption of air in traction motors, due to an increase of speed.

It is assumed that the consumption of air must be in proportion to the horse-power, and as the space passed over in a given time must be doubled, the horse-power, in which space is a factor, must be doubled, and the consumption of air doubled also.

This is true, but the consumption of air *per mile* is not doubled by doubling the speed. The consumption of air is in proportion to the resistances to be overcome, and within

reasonable and ordinary limits these resistances are but slightly increased by increase of speed. It is an error, also, to suppose, as many do, that in trolley motors an electrical attraction between the wheel and rail increases adhesion.

In support of these positions, authorities will be quoted. Oscar T. Crosby, in *Transactions* of American Institute of Electrical Engineers for August and September, 1894, states: "The adhesive coefficiency between the wheel and the rail is not increased in any practical degree by the passage of the current. In other words, there is no electrical attraction, as some suppose, between the wheel and the rail to increase adhesion. The adhesion is due to the weight on drivers alone."

The train resistances at high speeds do not increase, as is usually supposed, as the square of the velocity. At 86 miles per hour the total resistance per ton was only 13·4 pounds; 347 tons were carried at 86 miles per hour on a line by an expenditure of 1,068 horse-power.

The resistance of the air is a function of the first instead of the second power of the velocity.

From 40 to 80 miles per hour, the tonnage coefficient is practically 8 pounds per ton on first-class roads and best rolling stock.

Wellington, in his popular work on engineering, pages 922–924, makes statements as follows:

"Journal friction is variable, and is usually taken at 8 pounds per ton.

"The load per square inch on journal bearing has very little influence upon the friction.

"The velocity of the lowest journal friction is from 10 to 15 miles per hour.

"With good lubrication there is very little increase of journal friction up to 55 miles per hour.

"The coefficiency of journal friction is approximately constant at velocities from 15 to 50 miles per hour.

"The power required to overcome inertia and accelerate trains is about three times as much as to maintain velocity.

"The additional power required to get up speed is 45 pounds per ton to give 15 miles per hour in 3,340 feet.

"The air resistance at 10 miles per hour is less than $\frac{1}{5}$ pound per square foot.

"The principal resistance, except axle resistance, is due to oscillation and concussion, which, at 10 miles per hour, may be taken at $\frac{1}{2}$ pound per ton."

The above quotations from standard authorities do not sustain the statement of the expert of the General Electric Company, who stated in a criticism upon an estimate of the writer, that "a calculation, which it is not necessary to enter into, will show that to make an approximation to the average speed of 20 miles per hour, 600 horse-power will be found *not* sufficient to do the work. Where the speed of an electric train is reduced to that assumed for the steam train (10 miles per hour) 300 horse-power will be found abundantly sufficient."

The inference would appear to be, that if the speed of an electric train is increased from 10 to 20 miles per hour, the power must be increased from 300 to 600 horse-power. If this be true, it is very bad for electricity, for it is not true in regard to either steam or compressed air. The power required must always be sufficient to overcome resistance, and if, as appears from the authorities quoted, the resistances are but slightly increased by increase of velocity, there cannot be any great increase of power required per mile of distance traversed as measured by consumption of air or steam. There must be some, of course, but in ordinary service it does not figure very largely in the expenses.

As practical tests are more satisfactory than theory, the writer requested Mr. Hardie to make a test of the consumption of air at different speeds, and report the result. The following is the report, under date of April 22, 1896:

FIRST TEST. LOAD, 19,150 POUNDS.

Speed.	*Cubic Feet per Mile.*
3·00 miles per hour, consumption of air	347
5·70 " " " " "	334
6·81 " " " " "	488
7·57 " " " " "	335
7·80 " " " " "	568
8·50 " " " " "	452
9·70 " " " " "	388

Speed.	*Cubic Feet per Mile.*
10·10 miles per hour, consumption of air	560
10·30 " " " " "	275
11·40 " " " " "	604
12·30 " " " " "	421
13·00 " " " " "	538
13·70 " " " " "	447
16·70 " " " " "	450
17·05 " " " " "	447
22·80 " " " " "	445

SECOND TEST. LOAD, 24,990 POUNDS.

12·27 miles per hour, consumption of air	334
15·34 " " " " "	449

THIRD TEST. LOAD, 26,100 POUNDS.

6·70 miles per hour, consumption of air	437
8·00 " " " " "	452
10·34 " " " " "	470

FOURTH TEST. LOAD, 36,000 POUNDS.

5·25 miles per hour, consumption of air	632
7·50 " " " " "	582
8·56 " " " " "	589
15·34 " " " " "	334

The above results are very remarkable. The ordinary pressure gauges are not very sensitive, but it is impossible, from the above table, to infer that there was any increased consumption of air per mile, either with a largely increased speed or a considerable increase of weight. When a train is in motion, the draw-bar pull is but slightly increased by a moderate increase of speed. The great losses of power are in acceleration and retardation in starting and stopping.

It has been stated that the power required on a good track to start a street car is 116 pounds per ton, and to maintain it in motion 13 to 17 pounds. On a bad track, 134 pounds to start and 35 pounds to maintain.

Mr. Hardie has found by tests upon his motor that 130 successive applications of the brake consumed, by gauge pressure, 85 cubic feet of free air, equivalent to 0·65 cubic feet for each application.

Franklin L. Pope is authority for the following statement:

"A 16-foot trolley car, weighing about 14,000 pounds, requires eighteen seconds to get up speed and 10 horse-power to run 10 miles per hour, or 1 horse-power per mile per hour at car axle. Three times this power is required during the eighteen seconds of starting."

Frank S. Sprague, in New York *Evening Post*, of February 8, 1896, states that on the Third Avenue Elevated Railroad the maximum effort in the propulsion of trains is seven times the mean traction on a level; and that to start a train, accelerate to 20 miles per hour and bring it again to rest, consumes eighty seconds.

David L. Barnes estimates that an elevated train of 130 tons can be accelerated to 30 miles per hour in a distance of 1,250 feet, and brought to rest in half that distance.

OTHER USES FOR COMPRESSED AIR.

Compressed air affords the most economical means for the transmission of power to long distances. It has been claimed that electrical power generated from waterfalls could be transmitted hundreds of miles, but the writer has attempted to show in a monograph that is too voluminous to quote, that in the present condition of the science, power by electricity cannot be economically transmitted in competition with power furnished locally by coal, to a greater distance than about 20 miles. Long electrical transmission requires excessively high voltages, which are almost impossible of permanent and successful insulation, and instantly destructive to life in case of accidental contact. The late lamented Franklin Leonard Pope, in a letter to the writer, used this language: "A voltage of 20,000 may be possible in the future, but it has not yet been successfully accomplished. The difficulties seem to increase roughly as the square of the voltage; 10,000 volts is a wicked acting current, and when you double it, you had better watch out." He also adds: "The same speculative boomers who have put in 300 non-paying electric railroads throughout the country are now at work fostering a craze on electric power transmission. I am

sorry to see it, for it will end in discrediting all legitimate electric work. The mass of people will never learn to discriminate between the practicable and impracticable."

The transmission of compressed air requires high pressures, for the reason that increased pressure gives increased density and reduced volume and velocity. The loss in transmission being as the first power of the density and the square of the velocity, the loss in transmitting under 200 pounds would be ten times as great as under 2,000 pounds. High pressures are necessary for economical transmission both with electricity and air.

But compressed air and electricity are not properly to be considered antagonists; they may be made valuable auxiliaries.

A 6-inch pipe under an initial pressure of 2,000 pounds per square inch, and a terminal pressure of 10 atmospheres, or 147 pounds, will transmit nearly 8,000 horse-power to a distance of 10 miles, 5,700 horse-power to 20 miles, and 2,500 horse-power to a distance of 100 miles. Where there are mountain streams furnishing small powers at frequent intervals, a number can be concentrated in one pipe, and transmitted to furnish large power in distant localities. Compressed air, thus economically transmitted, can be used to generate electricity for local purposes. It can also be distributed to provide small powers, and also for ventilation and refrigeration in towns and cities.

The cable and electric systems, it is well known, are operated to best advantage economically at full capacity, but this is only for a few hours in the day. If surplus power were used to store air at high pressure in reservoirs the machinery could be shut down entirely or partially, and compressed air motors substituted at night and during the hours when full capacity is not required.

ELASTICITY OF THE SYSTEM.

An important advantage of compressed air motors is found in the fact that each motor is independent, and unaffected by any derangement of feed or trolley wires, cables or dynamos. They can run on any line, in connection

with any other system, and at any rate of speed. The introduction of air motors can be gradual; one motor can be tried, and, if satisfactory, the number can be increased to a full equipment. The steam required for electric or cable lines can furnish the little that is required for an experimental compressor, and will be more than sufficient for a full equipment. No outside expenditure whatever is required—no conduits, poles or wires. In this respect it differs from other systems, and permits a test to be made at a minimum of cost; but compressed air motors can no longer be considered as experiments. While they may not have attained the utmost limit of perfection of which they are capable, the experience in Europe, in Rome, N. Y., and in the City of New York, should be sufficient to satisfy the most skeptical.

SPEED VARIATIONS IN CRANK SHAFTS.

By George P. Starkweather.

A portion of the following discussion has appeared in cruder form in two numbers of the *Yale Scientific Monthly*, a magazine conducted by and for the students of the Sheffield Scientific School. Subsequently the writer pursued the matter further, and thought the whole to be of sufficient interest to warrant a wider publication.

The so-called exact method of discussing engine dynamics, as given in Prof. D. S. Jacobus' paper (see *Trans. A. S. M. E.*, Vol. XI), is inexact in one particular, namely, that in calculating the acceleration of the reciprocating parts of the engine the angular speed of the crank is assumed to be constant. The error thus introduced, however, is inappreciable. As this method is very laborious, the following simpler one is given, which, excepting that it does not take friction into account, is quite as exact. It has the drawback that the only joint pressure obtainable is the tangential component of the crank-pin pressure. Afterwards, a method for correcting the above-mentioned error is shown.

In *Fig. 1*, *a-c-e-f* is the indicator diagram, the back and full pressure lines being taken, of course, from opposite cards, so as to obtain the effective piston pressure; $O\,P$ is the crank, $P\,B$ the connecting rod, G the center of gravity of the latter, and C its instantaneous center of motion. Let M be the mass of the rod, and I_1 its moment of inertia about G. In obtaining M, I_1 and the position of G, the mass of the piston, piston-rod and crosshead is considered as a part of the connecting-rod concentrated at B; this is evidently allowable so far as considerations of energy are concerned.

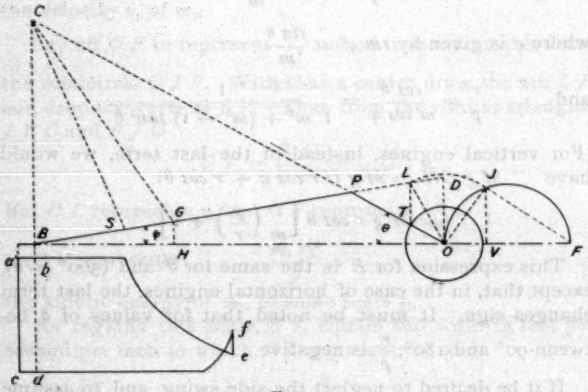

FIG. 1.

Let I' be the moment of inertia of the rod about C, and w' its angular speed about the same point, w_a being the average angular speed of the crank. Represent $O\,P$, $G\,P$, $B\,P$, $G\,H$, $C\,P$ and $C\,G$ by r, $l\,r$, $m\,r$, h, p and a, respectively. Then the energy of the rod is $E = \frac{1}{2}\, I'\, w'^2 + M\, g\, h$, the potential energy due to the weight being reckoned from the level $B\,O$. (For vertical engines, instead of h, we would use $O\,H$.)

Now,
$$w' = \frac{r\, w_a}{p}$$

and
$$I' = I_1 + M\, a^2;$$

so $$E = \frac{r^2 w_a^2}{2 p^2} (I_1 + M a^2) + M g h.$$

Also, $$a^2 = l^2 r^2 + p^2 - 2 p l r \cos(\theta + \varphi),$$

and $$h = \frac{(m - l)}{m} r \sin \theta;$$

so

$$E = \frac{w_a^2}{2} \left[\left(\frac{r}{p}\right)^2 (I_1 + M r^2 l^2) - \left(\frac{r}{p}\right) \left\{ 2 l M r^2 \cos(\theta + \varphi) \right\} + M r^2 \right] + M g \frac{(m - l)}{m} r \sin \theta,$$

where φ is given by $\sin \varphi = \frac{\sin \theta}{m}$,

and $$\frac{r}{p} = \frac{\cos \theta}{m \cos \varphi} = \frac{1}{\sqrt{m^2 + (m^2 - 1) \tan^2 \theta}}.$$

(For vertical engines, instead of the last term, we would have $M g \overline{OH} = M g (l r \cos \varphi + r \cos \theta)$

$$= M g r \cos \theta \left[\frac{l}{m} \left(\frac{p}{r}\right) + 1 \right].$$

This expression for E is the same for θ and $(360° - \theta)$, except that, in the case of horizontal engines, the last term changes sign. It must be noted that for values of θ between 90° and 180°, $\frac{r}{p}$ is negative.

If it be desired to neglect the side swing, and to assume that the connecting rod has the same motion as the piston, which is commonly done, we have only to set l, I_1 and h equal to m, o and o, respectively. We have then

$$E = \frac{M r^2 w_a^2}{2} \left[m^2 \left(\frac{r}{p}\right)^2 - 2 m \left(\frac{r}{p}\right) \cos(\theta + \varphi) + 1 \right].$$

But E can be obtained graphically with the greatest simplicity. We may consider the connecting-rod to consist of two material particles, provided these have the same total masses, the same center of gravity and the same inertia about that center. Let m_1 and m_2 be the masses of these particles, p_1 and p_2 their distances from G along the line of

the connecting-rod, and k the radius of inertia of the rod about G. Then

$$m_1 + m_2 = M, \quad m_1 p_1 = m_2 p_2, \quad m_1 p_1^2 + m_2 p_2^2 = M k^2,$$

which give $p_1 p_2 = k^2$.

Choose p_2 such that m_2 will lie at P, and let S be the corresponding position of m_1. Draw a circle of radius $O T$ such that $O T : O P = B S : B P$. Where this intersects $O P$ project vertically to L, on the connecting-rod line. Then as the triangles $O P L$ and $C P S$ are similar, if we take $O P$ to represent the velocity of the crank-pin, $O L$ will represent the velocity v_1 of m_1.

Lay off $O F$ to represent $\frac{2}{m_1}$, and on it as a diameter draw the semicircle $O J F$. With O as a center draw the arc $L J$, and drop the vertical $J V$. Then from the similar triangles $J V O$ and $F J O$

$$O V = \frac{O J^2}{O F} = \frac{O L^2}{O F}.$$

But $O L$ represents v_1 and $O F$ represents $\frac{2}{m_1}$;

so $O V$ represents $\frac{m_1 v_1^2}{2}$,

the kinetic energy of m_1, to some scale s_1.

As regards this scale, if s_2 equals the scale in feet per second per inch to which $O L$ represents v_1, and

$$s_3 = \frac{2}{m_1 O F},$$

$O F$ being measured in inches, it is easily shown that

$$s_1 = \frac{s_2^2}{s_3}.$$

The kinetic energy of m_2 can be easily found, it having the velocity of the crank-pin, assumed as constant. Adding this to that of m_1, and measuring h, the total energy E is obtained.

Here again, if we consider the connecting-rod to have the same motion as the piston, m_1 becomes M (sometimes taken $\frac{3}{8} M$) and $O L$ becomes $O D$.

When the crank is at the dead point let the energy be E_o. Then, as p, a and h become $m\,r$, $(m-l)\,r$ and o, respectively,

$$E_o = \frac{w_a^2}{2\,m^2}[I_1 + M\,r^2\,(m-l)^2],$$

to which must be added for vertical engines $M\,g\,r\,(l+1)$. Let W be the work done by the expanding fluid while the crank has turned through the angle θ; this is the area *a-b-c-d* in the figure, and can easily be determined by planimeter or ordinates. Since the energy of the connecting-rod has changed from E_o to E, the work transmitted to the crank-pin is $W-(E-E_o)$. In *Fig. 2* lay off as an abscissa $N\,L$ to represent θ, and as an ordinate $L\,M$ equal to this total work transmitted to the crank-pin; plotting in this way we obtain a curve of total crank-pin work $N\,M'\,M\,Q$. The resistance being in general constant, the work done

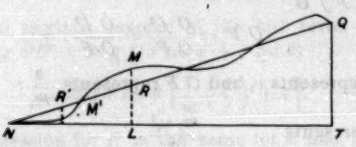

FIG. 2.

upon it is represented by a straight line, and since for a revolution it is the same as the work done on the crank-pin, the line is $N\,R\,Q$.

Consequently, $R\,M$ represents the energy gained by the fly-wheel while it has turned the angle θ, for it is the difference between the work received at the crank-pin and that transmitted by the belt. Measure the greatest positive and negative values of this, $R\,M$ and $R'\,M'$; their sum represents the fluctuation of fly-wheel energy K, and the fly-wheel inertia is obtained by substitution in the usual formula

$$I = \frac{K}{k\,w_a^2}$$

where k is the coefficient of unsteadiness allowed.

$R\,M$ probably cannot be measured accurately, owing to the scale of the drawing. It is accordingly better to measure

$N\ L$ or θ corresponding to $R\ M$. This can be very exactly determined, as it is convenient to take the scale of abscissas large; also, $R\ M$ being a maximum, a small error in θ will affect the result very slightly. With this value of θ find the value of $L\ M$ by the formulæ given, and $L\ R$ by the similar triangles $N\ L\ R$ and $N\ T\ Q$. This gives $R\ M$, and in like manner $R'\ M'$.

This curve of total crank-pin work is mentioned by Prof. Cotterill, in his *Applied Mechanics*. He does not take the inertia of the reciprocating parts into account, however, and in this case it is, as he states, a longer method than that by resolution of forces. But, in the writer's opinion, it is a shorter method when the inertia is to be considered.

The slope of the curve is proportional to the tangential component of the crank-pin pressure; where the slope changes sign indicates a reversal of that pressure. Where the curve crosses the line $N\ Q$ gives us the crank positions at which the fly-wheel has the same speed as at the dead point, and, in general, any ordinate $R\ M$ gives the energy of the fly-wheel as related to its energy at the dead point. In our present case, the maximum $R\ M$ is much greater than the minimum $R'\ M'$, so the angular speed of the fly-wheel at the dead point is probably less than the mean speed.

The preceding determines the fly-wheel inertia to control the speed fluctuation as desired. Let us now suppose this inertia to be given or determined; we have to find the speed variations. It will be observed that if we find the speed at any one point, we have indirectly from *Fig. 2* the speed at every point, since, knowing the inertia of the fly-wheel, we know the difference between the square of the velocity at any point and that at the given point. Transfer the ordinates $R\ M$ to a horizontal base line, obtaining a curve as in *Fig. 3*. Draw $P\ S$ horizontal at such a distance below $N\ R$ that some ordinate $M\ Q$ represents the kinetic energy of the fly-wheel at that moment. Then the ordinates from $P\ S$ give directly $\frac{1}{2}\ I\ w^2$, indirectly w, the angular velocity at any point. We have to find one ordinate.

A writer in London *Engineering*,* who obtains this curve in a different manner, finds an ordinate by making either of two assumptions:

(1) That the energy at the average speed is the mean of the extreme energies.

(2) That the average speed is the mean of the extreme speeds.

The latter is the assumption commonly made.

In the first case, calling w_1 and w_2 the extreme speeds,

$$\tfrac{1}{2} I w_a^2 = \tfrac{1}{4} I (w_1^2 + w_2^2).$$

We have also $\tfrac{1}{2} I w_1^2 - \tfrac{1}{2} I w_2^2 = R M + R' M'$,

from which $\tfrac{1}{2} I w_1^2 = \tfrac{1}{2} (R M + R' M' + I w_a^2)$,

giving the distance of $P S$ below M.

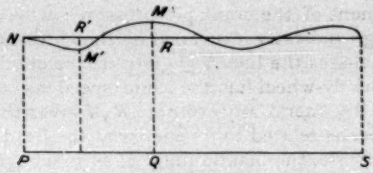

FIG. 3.

In the second case $w_a = \tfrac{1}{2} (w_1 + w_2)$,

also $\tfrac{1}{2} I w_1^2 - \tfrac{1}{2} I w_2^2 = R M + R' M'$,

from which

$$\tfrac{1}{2} I w_1^2 = \frac{(R M + R' M' + 2 I w_a^2)^2}{8 I w_a^2}.$$

But the ordinate $N P$ can be found exactly without any assumptions by determining w_o, the speed at the dead point, in the following manner: Call y any ordinate from $N R$ of the curve in *Fig. 3*, abscissas θ being measured from N. Then

$$\tfrac{1}{2} I (w^2 - w_o^2) = y \qquad w = w_o \left(\frac{2y}{I w_o^2} + 1\right)^{\frac{1}{2}}$$

or

$$\frac{d\theta}{dt} = w_o \left(\frac{2y}{I w_o^2} + 1\right)^{\frac{1}{2}}$$

* **22**, 1, 37.

from which $$d\,t = \frac{d\,\theta}{w_o}\left(\frac{2\,y}{I\,w_o^2} + 1\right)^{-\frac{1}{2}}.$$

Now, in every possible case, y will be less than $\frac{1}{2}\,I\,w_o^2$, for the alternate condition would mean that the resistance is so great that the engine comes to rest. So we can develop

$$\left(\frac{2\,y}{I\,w_o^2} + 1\right)^{-\frac{1}{2}}$$

by the binomial theorem in ascending powers of $\frac{2\,y}{I\,w_o^2}$, obtaining

$$dt = \frac{d\,\theta}{w_o}\left(1 - \frac{y}{I\,w_o^2} + \frac{3}{2}\frac{y^2}{I^2\,w_o^4} - \frac{5}{2}\frac{y^3}{I^3\,w_o^6} + \text{etc.}\right)$$

Integrating for θ between the limits o and $2\,\pi$, and for t between o and one period, $\frac{2\,\pi}{w_a}$,

$$\frac{2\,\pi}{w_a} = \frac{2\,\pi}{w_o} - \frac{1}{I\,w_o^3}\int_o^{2\pi} y\,d\,\theta + \frac{3}{2\,I^2\,w_o^5}\int_o^{2\pi} y^2\,d\,\theta - \frac{5}{2\,I^3\,w_o^7}\int_o^{2\pi} y^3\,d\,\theta + \text{etc.}$$

Call these integrals respectively S_1, S_2, S_3, etc. Then

$$\frac{2\,\pi}{w_a} = \frac{2\,\pi}{w_o}\left(1 - \frac{S_1}{2\,\pi\,I\,w_o^2} + \frac{3\,S_2}{4\,\pi\,I^2\,w_o^4} - \frac{5\,S_3}{4\,\pi\,I^3\,w_o^6} + \text{etc.}\right)$$

or,

$$w_o = w_a\left(1 - \frac{S_1}{2\,\pi\,I\,w_o^2} + \frac{3\,S_2}{4\,\pi\,I^2\,w_o^4} - \frac{5\,S_3}{4\,\pi\,I^3\,w_o^6} + \text{etc.}\right)$$

S_1 is the area in *Fig. 3* included between the curve and the line $N\,R$, areas below that line being reckoned as negative. S_2 is twice the statical moment of the area about $N\,R$, all areas being considered as having a positive moment. S_3 is three times the second moment, or "moment of inertia" of the area about $N\,R$, the moment of all areas below $N\,R$ being reckoned negatively; similarly for S_4, etc. These quantities can be determined most easily by the integraph; in any case it is best to take the parts of the curve above

the line separately from those below, adding with the proper signs afterwards.

The terms in S in the last equation are all small, and decrease in magnitude very rapidly. In fact, if k is the coefficient of unsteadiness, the terms in S_1, S_2 and S_3 are less than $\frac{1}{2}k$, $\frac{3}{8}k^2$, and $\frac{5}{16}k^3$, respectively, particularly so in the case of S_1 and S_3. To find w_0, dropping the terms in S, we find $w_0 = w_a$. Substituting this for w_0 in the neglected terms, solve again for w_0, repeating as often as necessary.

We have thus found w_0, and hence w for every crank position. We are accordingly able to make a first correction for the inaccuracy in the "exact" method, already mentioned; for in obtaining the energy of the reciprocating parts, or the force necessary to accelerate them, we are able to use a first approximation to their true velocities and accelerations, instead of taking values based on a uniform crank speed. The curve in *Fig. 3* can then be determined anew, and further approximations made as often as desired.

It is not claimed that the last discussion given is easy of application, or, indeed, useful practically, but it completes the solution of the speed variations.

ANNUAL REPORT OF THE BOARD OF MANAGERS OF THE FRANKLIN INSTITUTE.

(For 1896.)

The Board of Managers of the Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, respectfully presents the following report of the operations of the Institute for the year 1896:

MEMBERS.

Members at the close of 1895	1,905	
Number of new members elected who have paid their dues in 1896	84	
		1,989
Lost by death, resignation and non-payment of dues,		122
Total membership at the end of 1896		1,867

FINANCIAL STATEMENT.

Balance on hand, January 1, 1896		$17 13
Receipts:		
Receipts from members, annual	$6,364 00	
Receipts from members, life	200 00	
Income from Endowment Funds in hands of the Board of Trustees	1,886 69	
Income from Bloomfield H. Moore Fund	382 24	
Income from Memorial Library Fund	30 73	
Interest on a part of the investment of New Building Fund	340 00	
Interest on B. H. Bartol Fund	50 00	
Interest on investments of Institute's funds	611 66	
Temporary loan	3,000 00	
Cash from subscriptions to, and sales of, the *Journal*, from fees for drawing school, and from other sources	4,864 25	
		17,729 57
		$17,746 70
Payments:		
Committee on Library	$1,045 79	
Bloomfield H. Moore Fund expenditures	407 46	
Memorial Library Fund expenditures	56 00	
Committee on Instruction	983 45	
Curators	1,927 63	
Insurances	541 04	
Salaries and wages	4,623 75	
Temporary loan	500 00	
Interest on temporary loan	450 39	
Life membership fees handed over to the Trustees under amended By-Laws	300 00	
Dues and entrance fees of non-resident members handed over to Trustees for *Journal* endowment	118 00	
Other expenditures	6,596 20	
		$17,549 71
Balance on hand, December 31, 1896		$196 99

ENDOWMENT FUNDS.

The Permanent Endowment Funds of the Institute, at the end of 1896, consist of the following:

(In the hands of the Institute.)

Bloomfield H. Moore Memorial Fund	$15,000 00	
Memorial Library Fund	1,000 00	
B. H. Bartol Fund	1,000 00	
Amount received from Life Memberships between January 1, 1891, and October 1, 1894	1,755 00	
		$18,755 00

(In the hands of Elliott Cresson Trustees.)

The Elliott-Cresson Medal Fund (approximate)		4,500 00

(In the hands of the Board of Trustees of the Franklin Institute.)

The legacy of George S. Pepper	$35,687 50	
The legacy of Eugene Nugent	1,000 00	
The Edward Longstreth Medal Fund	1,000 00	
The donation of an unknown friend	5 00	
The donation of Sigmund Riefler	20 00	
Life membership fund since October 1, 1894	750 00	
Journal Endowment Fund	138 00	
By will of John Turner, deceased, one-fourth of net income on 2 per cent. of his residuary estate, yielding about $50 or more per year, equivalent to a capital sum of	1,000 00	39,600 50
Total		$62,855 50

An increase in 1896 of $438.00.

During the ten years, from 1886 to 1896, the permanent endowment funds have grown from $11,000 to $62,855.50.

LIBRARY.

The details of the operations of the library appear elsewhere in the Committee's Annual Report.

As regards additions, the exhibit for the year is not as favorable as that of the several preceding years, but substantial progress has been made in the work of cataloguing, the benefits of which will be permanent, and considerable additions have been made by devoting a large proportion of the committee's appropriation to the binding of periodicals.

The comparatively poor exhibit of this branch of the Institute's work, it should be said in justice to the Committee on Library, is due to the failure to collect the interest on a portion of the B. H. Moore Fund. There is good reason, however, to believe that (through the intervention of the Solicitor of the Institute) the arrearages of interest will be fully collected during the present year, and that the library exhibit for the year 1897 will be a marked improvement over that of 1896.

The Board, at the suggestion of the Committee on Library, has added to the precautions to protect the library from danger of fire, by bricking up the

back windows on the second and third floors, except in the Secretary's office and the Board room, and tinning the doors and windows.

THE JOURNAL.

The financial statement of the *Journal* for the year 1896 is not as favorable as could be desired, the prevailing depression in business having been felt severely in its operations. This has manifested itself very clearly in the falling off in the sales of sets and extra copies, and also in its receipts from advertisements. As a consequence, the committee reports for the year a small deficit. The prospects for the new year, however, are most encouraging, and with the advent of the business activity, which is hopefully anticipated, the deficit should be more than covered during the year 1897. The Board wishes to express its high appreciation of the manner in which the editorial branch of the *Journal* has been conducted, and of the sound discretion with which its business affairs have been managed by the Committee on Publications.

COMMITTEE ON SCIENCE AND THE ARTS.

The work of this Committee exhibits a degree of activity which compares favorably with that of recent years, and a distinct improvement in respect of its internal organization. The efficiency of the Committee is believed to be greater than at any previous period of its existence, and the character of its work reflects credit upon the Institute.

The details of this Committee's operations appear in its annual report.

INSTRUCTION.

The lecture courses arranged by professors of the Institute, in co-operation with the Committee on Instruction, have fully maintained the high character for excellence which has distinguished them for many years. Many of these lectures are published in the *Journal* and contribute largely to the value and interest of its pages. The Board would, therefore, recommend that the thanks of the Institute be voted to its professors and to the lecturers for their services.

The Board regrets to be obliged to note a falling off in the number of pupils attending the drawing school; but believes that this is fully accounted for by the continued business depression. With the removal of the cause, the patronage of the school should correspondingly improve. With the character of the work accomplished in the school, the Board expresses its cordial approbation.

The branch school at Germantown Junction, established in 1894, has enjoyed a steady growth, and is now self-supporting.

SECTIONS.

The Chemical and Electrical Sections make a satisfactory exhibit of work accomplished during the past year. The annual reports of these Sections are herewith transmitted.

EXHIBITIONS.

The Board has been duly impressed with the importance of seizing the first favorable opportunity that should present itself for the holding of an exhibition, but, until quite recently, the continued business depression and the necessity of providing a special building for such purpose have appeared to the Board to be circumstances which would render the financial outcome of an exhibition gravely questionable. At the present time it is gratifying to the Board to be able to state that the outlook for an enterprise of this kind is much more favorable, and the Board believes it will be in a position to carry into effect the project of an exhibition, to be devoted to the textile industries, during the year 1897. The action of the Board upon the preliminary report of its Committee on Exhibitions will give the members of the Institute all the facts bearing on this important undertaking.

GENERAL REMARKS.

The Board has, a number of times, in previous years, dwelt upon the wants of the Institute and of its valuable library, as to an enlarged fire-proof building and the accumulation of an ample maintenance fund to be vested in the hands of the Trustees, the income from the same to be applied to the maintenance and advancement of the Institute work.

The Institute has been operated upon an exceedingly economical basis, and the expenditures for maintenance cannot be further reduced without seriously crippling its usefulness.

The imperative need of a larger income must be evident to any one who will examine the annual reports of the Board for some years back.

A new Standing Committee on Endowment was appointed recently by the Board, to make another effort for the raising of a maintenance fund, and it is hoped that its labors may meet with some success. One hundred thousand dollars would do very much towards relieving the Institute of the difficulties connected with its annual expenses. At the same time an increase of the membership, especially of life members, the receipts from which are added to the permanent endowment fund, would substantially aid the cause. There ought to be sufficient interest in the Franklin Institute, among the manufacturers of this great city, to enable this committee to make a success of its undertaking.

By order of the Board.

JOS. M. WILSON,
President.

NOTES AND COMMENTS.*

ALUMINUM ALLOYS.

ALUMINUM AND OTHER METALS.—With the exception of lead, antimony and mercury, aluminum unites readily with all metals, and many useful alloys of aluminum with other metals have been discovered within the last few years. The useful alloys of aluminum so far found have been largely in two groups, the one of aluminum with not more than 15 per cent. of other metals, and the other of metals containing not over 15 per cent. aluminum; in the one case, the metals imparting hardness and other useful qualities to the aluminum, and in the other the aluminum giving useful qualities to the metals with which it is alloyed.

More or less useful alloys have been made of aluminum with copper, chromium, tungsten, titanium, molybdenum, zinc, bismuth, nickel, cadmium, magnesium, manganese and tin, these alloys all being harder than pure aluminum; but it is by combination of these metals, with perhaps additions of lead and antimony, that alloys of most value have so far been discovered. Some are with additions of only 1 to 2 per cent. aluminum.

ALUMINUM AND TIN.—Tin has been alloyed with aluminum in proportions of from 1 to 15 per cent. of tin, giving added strength and rigidity to heavy castings, as well as sharpness of outline, with a decrease in the shrinkage of the metal. The alloys of aluminum and tin are rather brittle, however, and while small proportions of tin in certain casting alloys have been advantageously used to decrease the shrinkage, on account of the comparative cost and brittleness of the tin alloys, they are not generally used. Sometimes phosphor-tin is used to give additional hardness, together with good soldering properties, to aluminum alloys.

ALUMINUM AND NICKEL.—Nickel is one of the favorite hardeners used in alloying aluminum. In proportions of from 7 to 10 per cent. of nickel and the rest aluminum, the best casting metal is produced for purposes where toughness, combined with hardness and good casting qualities, is desired. "Nickel-aluminum" has become a trade name. Several new nickel and aluminum alloys for jewelers and other special work have been made. Two of these are: (1) 20 parts nickel and 8 parts aluminum; (2) 40 parts nickel, 10 parts silver, 30 parts aluminum, and 20 parts tin.

ALUMINUM AND MANGANESE.—Manganese is one of the best hardeners of aluminum; it can be cheaply added in aluminum casting metal by means of the rich alloys of ferro-manganese, and for rolling purposes, by adding the pure black oxide of manganese to the electrolytic bath in which the aluminum is produced. The alloys of manganese give special rigidity and hardness to aluminum; in combination with copper and nickel, one of the best hardening alloys of aluminum yet produced has been obtained.

* From the Secretary's monthly reports.

ALUMINUM AND TUNGSTEN.—The alloys of aluminum and tungsten have for the past few years been especially popular for rolled sheets and plates, to be afterwards spun. Under the trade name of "Wolfram-aluminum," the metal has been largely used for military equipments. The alloys of aluminum and tungsten can be advantageously used, with the addition of copper, and also with the triple hardeners, tungsten, copper and iron; or tungsten, copper and manganese; or as usually made, the aluminum is hardened with some copper; tungstate of sodium and ferro-manganese are added to the reducing bath, making an alloy of aluminum, copper, tungsten, manganese and iron.

ALUMINUM AND CHROMIUM.—Chromium, though rather expensive, is an especially advantageous hardener of aluminum. Aluminum hardened with chromium seems to retain its hardness, after annealing or being subjected to heat, better than almost any other of the alloys.

ALUMINUM AND TITANIUM.—Titanium alloys of aluminum, although hard to manufacture uniformly homogeneous, have greater spring and resilience than most other aluminum alloys. Alloys of titanium, chromium and copper, together with aluminum, give some of the hardest and toughest light alloys yet produced.

ALUMINUM AND ZINC.—Zinc is used as a cheap and very efficient hardener in aluminum castings, for such purposes as sewing-machine frames, etc. Proportions up to 30 per cent. of zinc with aluminum are successfully used. An alloy of about 15 per cent. zinc, 2 per cent. tin, 2 per cent. copper, ½ per cent. each of manganese and iron, and 80 per cent. aluminum, has special advantages.

ALUMINUM AND ANTIMONY.—These metals unite with difficulty, and only in bearing metals of the class of Babbitt metals have any useful alloys as yet been discovered.

ALUMINUM AND LEAD.—These metals unite with great difficulty, and no useful alloys have yet been discovered.

ALUMINUM AND COBALT.—This metal also acts, with about an equal amount of copper, as a specially good alloy for hardening aluminum.

The following are two cobalt and aluminum alloys used for special purposes: Sixty parts cobalt, 10 parts aluminum, 40 parts copper. Thirty-five parts cobalt, 25 parts aluminum, 10 parts iron, 30 parts copper.

GOLD AND ALUMINUM.—Prof. W. C. Roberts-Austen has discovered a beautiful alloy, composed of 78 parts gold and 22 parts aluminum, which has a rich purple color.

ALUMINUM AND CADMIUM.—These metals have been alloyed to produce a solder for aluminum, which seems to give good results. Cadmium does not appear to act appreciably as a hardener for aluminum, as do almost all other metals.

ALUMINUM AND BISMUTH.—These two metals combine easily, the alloys being very fusible, as might be expected of alloys with bismuth. They remain unchanged in the air at ordinary temperatures, but oxidize rapidly when melted. Bismuth makes aluminum very brittle. No valuable alloys of these two metals have as yet been discovered.

ALUMINUM AND VANADIUM.—Vanadium is a good hardener of aluminum, and can readily be alloyed with it, due to its presence in some of the bauxites that are native aluminum ores.—*Aluminum World.*

SCIENTIFIC BREVITIES.

From the *Scientific American*, we learn that M. Raoul Pictet, who has done much original chemical work at low temperatures, suggests that by making use of *low temperatures* syntheses may be effected which would be otherwise impossible. In many chemical operations the heat generated so raises the general temperature of the bodies acted upon that all control over the combination is lost. At very low temperatures, however, all chemical action ceases. By choosing the right temperature, therefore, reactions between substances may be made to take place as slowly as desired. By this means M. Pictet has effected combinations that are impossible at ordinary temperatures.

Experiments show that a *light of 1 candle-power* is plainly visible at 1 mile, and one of 3 candle-power at 2 miles. A 10 candle-power light was seen with a binocular at 4 miles, one of 29 at 5 miles, though faintly, and one of 33 candles at the same distance without difficulty. On an exceptionally clear night a white light of 3·2 candle-power can be distinguished at 3 miles, one of 5·6 at 4 and one of 12 at 5 miles.

M. Moissan has found that when *acetylene* is allowed to impinge upon pyrophoric iron, which has been reduced by hydrogen at the lowest possible temperature, the gas is decomposed with incandescence into its constituents. At the same time condensation takes place, and a liquid hydrocarbon, rich in benzine, is produced. The same result is obtained if pyrophoric nickel or cobalt is substituted for the iron. No gaseous compound of either metal is obtained, and he concludes that the decomposition is due to physical causes.

The same author, who has lately prepared *pure uranium*, states that it is whiter in color than iron, can be filed with ease and does not scratch glass. If very finely divided, it decomposes water at the ordinary temperature.

Kozlowski, of Berlin, has introduced *double glass globes for gas lamps*, which contain in the annular space a very dilute aqueous solution of copper sulphate, to which a trace of ammonia has been added. The purpose of this improvement is to cut off the heat rays and to give the light a slight tinge of blue.

ALUMINUM MANUFACTURE IN EUROPE.*

The first works on a commercial scale in Europe—and, indeed, in the world—for the manufacture of aluminum were located in France. From the early commercial work of Deville, at Javel, under the auspices of Emperor Napoleon III, and of Charles and Alexander Tissier, at Rouen, in 1854–55 (who sold their metal at from $2 to $4 per ounce), the Société Anonyme de l'Aluminium, for working and selling aluminum, came into existence with works for making the metal, first at Glaciére, then at Nanterre and later at the chemical works of H. Merle & Co. at Salindres, where, for many years under their proprietorship, and later of Pechiney & Co., the manufacture of aluminum was successfully conducted.

In their first successful work cryolite (the double fluoride of sodium and aluminum) was used as the ore from which to reduce the metal, and later—and more efficiently—chloride of aluminum (Al_2Cl_6) was used as the salt of the metal from which to reduce it by the means of sodium. This firm produced some of the best aluminum that has ever been put upon the market, and earned for the metal praises for properties which later experience with inferior and more impure metal has often not substantiated, to the serious retarding of the introduction of the metal in the arts. Too much praise cannot be bestowed upon these early manufacturers of the metal, who, for more than thirty years from the year 1857, were not only pioneers, but practically were alone in the field. These works enjoyed a practical monopoly of the aluminum business of the world for more than twenty-five years, although there were unsuccessful business enterprises started in England, the first, in 1859, by C. H. Gerhart, at Battersea, a suburb of London, which only ran for a short time; and later, in 1860, by Bell Brothers, at Newcastle-on-Tyne, who made aluminum in a desultory way up to the year 1874.

In 1882 the selling price of aluminum, which had been reduced to about $12 to $14 per pound, was further lowered by the process of an Englishman named Webster, who started a company called the Webster Aluminum Company. Mr. Webster's improvements consisted in a cheaper production of aluminum chloride, used as the salt from which the metal was best reduced by the sodium process. The business of this company was further strengthened by the purchase of the patented process of H. Y. Castner for making the reducing agent, sodium, by an improvement by which a more intimate contact is effected of the carbon used as a reducing agent of the sodium from molten caustic soda. This company developed in June, 1887, into the Aluminum Company, Limited, with a share capital of £400,000, and put up expensive works at Oldbury, near Birmingham, England, for making aluminum chloride, metallic sodium, and from them, metallic aluminum. Among the shareholders of this company were some of the best chemists and metallurgists, as well as some of the most prominent politicians, of Great Britain.

Early in the year 1888, another rival company to the Aluminum Company, Limited, was started at Wallsend, a suburb of Newcastle-on-Tyne, to

* From "The Mineral Resources of the United States," 1895. Dr. David T. Day. Washington, D. C.

work the process of Carl Netto. This process consisted in using molten cryolite as the salt from which to reduce the aluminum, the metallic sodium being made in a furnace by the trickling of molten caustic soda over incandescent coke. Soon after getting into operation, these two companies unfortunately got into legal complications regarding their respective patent rights, and the curious spectacle was presented of these two large and financially strong companies fighting over the patent rights to a process that was destined to prove, before the settlement of the suit, uneconomical as compared with the Hall electrolytic process, that was even at that time being successfully developed in Pittsburgh, Pa. Both of these companies, in the year 1890, stopped the manufacture of aluminum by the modifications of the old Deville process of reduction by means of metallic sodium. Early in the year 1891, the firm of Pechiney & Co. also ceased operations in the manufacture of aluminum; for by this time the selling price of aluminum had been reduced to $1.50 per pound—a rate far below the cost of manufacture of aluminum by the sodium process.

In August, 1891, the selling price was again reduced to 50 cents per pound. The European price for pure aluminum fell, to meet the American competition, to the following prices:

EUROPEAN PRICES OF ALUMINUM.

	Wholesale Price per Pound.	*Retail Price per Pound.*
September 1, 1890, to March, 1891	$1 67	$1 83
March to July 20, 1891	1 32	1 45
July 20 to October 1, 1891	78	88
October, 1891	70	88
November, 1891, to July, 1893	55	66

This rate of 50 cents per pound was far lower than it could be hoped that any sodium reducing process for the manufacture of aluminum could attain, and they all forthwith quit the business, although the meritorious Castner process of manufacturing sodium was developed by the Aluminum Company, Limited, within the next three years to the rate of about 25 cents per pound, that Company having achieved financial success in the manufacture and sale of metallic sodium made by the Castner electrolytic process at Oldbury, England.

Ludwig Grabau, of Hanover, Germany, in 1889, devised processes for making cheaply fluoride of aluminum from kaolin by means of decomposition with sulphuric and hydrofluoric acids; also pure and cheap metallic sodium by the electrolysis of fused common salt, and made some very pure aluminum in 1890. His work was also one of those ruthlessly cut short by the drop in price to 50 cents per pound.

There were several poorly-devised processes, in which the use of an electric current had been called into service, that were as well "given their quietus" by the drop in price to 50 cents per pound for aluminum in 1891. Among these were the following:

(1) Aluminum and Magnesium Fabrik, at Hemelingen, near Bremen. This company at first, from 1884 to 1887, used the process of Grätzel, who

suggested the electrolysis of the chloride or fluoride of aluminum, using compound anodes of part carbon and part alumina. The process was a failure because of the polarization around and excessive wear of the anodes, and because of the non-continuity of the process, as well as because of the expense of the aluminum halogen salts used as the source of the decomposition by the electrolytic action. This company later (1888–1890) used a modification of the Devill sodium process, under the direction of their manager, Herr Saarburger.

(2) The process of Dr. Edward Kleiner, of Zurich, Switzerland, patented in England early in the year 1886, and based on the electrolysis of cryolite, which was electrolyzed after being first melted by the aid of the electric current, as had been first suggested by the work of Sir Humphry Davy and later was published in many forms during the interim between his day and the time when cheap and efficient electrical generators made such a process as Hall's a practicable undertaking. The Kleiner process was started at Hope Mills, Tyddesley, Lancashire, England, and failed, like its predecessor, the Grätzel process, for similar reasons. Its last hopes as a successful process, indeed, waned with the reduction of price to $1.50 per pound, in 1889. The electrical plant of the Kleiner works was purchased by the Pittsburgh Reduction Company, to be used in working its foreign patents.

(3) The process of Adolph Minet, which consisted in the electrolysis of a molten bath of fluoride of aluminum, together with the chloride of sodium, fed by the addition of fresh aluminum fluoride and alumina. From 1888 to 1890 this process was experimented on at Creil, in France, and in 1890 was started on a larger scale at St. Michel, using a water-power of the Vaillorette, a stream running into the Arc River, in High Savoy. This process was worked by the Bernard Brothers, of Paris, who lost money upon the unsuccessful working of the process. Their plant, like that of Kleiner, has since been sold to a firm working under the Hall patents.

(4) The Hérault process for manufacture of aluminum alloys, first put into practical operation on July 30, 1888, at the works of the Société Métallurgique Suisse at the Falls of the Rhine, Neuhausen, Switzerland. In this process alumina is reduced in the presence of carbon and a cloaking metal, like copper or iron, to alloy with the reduced aluminum, by means of the intense heat produced in a powerful electric arc. The Hérault alloy process was abandoned upon the advent of the 50-cent rate for aluminum, in works that had been in operation under the proprietorship of a stock company (the Aluminium-Industrie-Actien-Gesellschaft), at Neuhausen, Switzerland, and at Froges (Isère), in France, as well as at Boonton, in the State of New Jersey.

The Aluminium-Industrie-Actien-Gesellschaft, formed with a share capital of 10,000,000 marks, by the uniting of the Société Électro-Métallurgique Suisse and the Allgemeine Electricität Gesellschaft, of Berlin, in November, 1888, purchased the Hérault continental patents and continued the work of manufacturing aluminum at Neuhausen. This new company soon found that the aluminum alloys made by their Hérault alloy process, which was not essentially an electrolytic process, were superseded in the world's market by

the pure aluminum made by the electrolytic process. It consequently gave up its more expensive alloy furnaces early in the year 1890, after having experimented with the pure aluminum process for some months, and devoted its attention to producing pure aluminum. From the year 1891 it has manufactured almost exclusively pure aluminum. Its present plant —which, by the way, is just at present considerably curtailed in its output of aluminum, on account of going into the manufacture of carbide of calcium with a portion of the available water-power—is limited to the taking from the river Rhine at the Rhine Falls, Neuhausen, of 20 cubic meters of water, equivalent to 700 cubic feet per second, which is conducted through steel penstocks to a fall of 20 meters, developing at a maximum about 5,500 effective mechanical horse-power, which is utilized in a manner to obtain about 3,000 horse-power in electrical current. The plant now consists of one 300 horse-power turbine, two 600 horse-power turbines, and five 610 horse-power turbines, of the Jonval type, one of the turbines being kept in reserve. The turbines have vertical shafts, and each actuates above it a generator of 7,500 ampères at a tension of 55 volts, or 553 electrical horse-power. With this plant running at full time, an output of between 3,000 and 4,000 pounds per day has been produced since the middle of the year 1893. This company has also secured further water-power rights by means of a canal and expensive tunnel, which is proposed to be driven later, when business will warrant, lower down at the Höllenhaken Rapids, Rheinfelden, on the Rhine, near Basle, where it is proposed to erect a plant having 20,000 horse-power capacity. The company has also secured another water-power right at or near Salzburg, Austria.

Following the parent company, the Aluminium-Industrie-Actien-Gesellschaft, the Société Électro-Métallurgique Française, which had established works at Froges (Isère) to manufacture aluminum alloys by the Hérault process early in 1889, soon gave up its alloy business, and in 1891 commenced to sell pure aluminum made by the electrolytic process of dissolving alumina in a molten bath of the fluoride of aluminum together with the fluoride of some metal or metals more electro-positive than aluminum, passing a direct electric current through the bath, and producing aluminum by the electrolysis of the alumina thus dissolved. Its plant at Froges was abandoned in 1893, and a much larger one at La Praz, on the river Arc, in Savoy, was established in 1894, designed to make only pure aluminum. This plant consists of two turbines, each running a generator of about 1,500 electrical horse-power, and its capacity is about 3,000 pounds of aluminum per day.

In the "survival of the fittest," with the lowered selling price of the metal, it will be seen, from the above hasty sketch of the history of the development of aluminum, that a report upon the present state of the art of aluminum manufacture in the years 1893, 1894 and 1895 would have shown in manufacturing operation in Europe only the works of the Aluminium-Industrie-Actien-Gesellschaft, at Neuhausen, Switzerland; the works of the Société Électro-Metallurgique Française, whose works during this period were removed from Froges (Isère) to La Praz, near Modane, on the river Arc, in Savoy, and the works at St. Michel, which, during this period, were

transferred from the hands of Bernard Brothers, who had been working the Minet process, to the Société Industrielle de l'Aluminium, a company which had bought the French patents of Hall from the Pittsburgh Reduction Company. These establishments, with the Pittsburgh Reduction Company in America, with works at New Kensington, Westmoreland County, Pa., near Pittsburgh, and at Niagara Falls, N. Y., were the only ones in the world that were in commercial operation during this period.

So far in the development of the metallurgy of aluminum, France, England, Germany, Switzerland and the United States have been the only countries of the world dividing the honors. In the future the countries having good water-powers will, undoubtedly, compete for the world's trade; and already, as before referred to, the Aluminium-Industrie-Actien-Gesellschaft has secured, in addition to another power on the Rhine, near Basle, Switzerland, a water-power in Austria for a future development of works. In Russia there are several large landed interests with water-powers, the advantages of which are being considered for the manufacture of aluminum. In Norway and Sweden there are also good water-powers which the new developments in electro-metallurgy are bringing into favorable consideration. A plant in Norway, at Sarpsfos, has been definitely decided upon. This plant has a capacity of 10,000 horse-power steadily during the entire year, the fall of the water, which it is proposed to utilize, being about 80 feet. There is a very large volume of water that can be utilized. This plant will probably not be in operation before the year 1898.

The disadvantages of most of the European water-powers that would seem to be in other ways available are their periods of low water in the winter and early spring season, when the snows of the mountain glaciers which feed their head waters, where water-powers are situated, are frozen up. Owing to the comparative slowness of operation of the present successful electrolytic process of manufacture of aluminum, continuity of operation seems to be an almost necessary prerequisite to economical manufacture, and a plant that would be forced to lie idle or work at a greatly reduced output for three months out of the twelve will undoubtedly be so seriously handicapped as to be unable to compete for the business of the future.

As to methods of manufacture, all the aluminum now being made in the world is practically made by the general process of the electrolytic decomposition of alumina, dissolved in a molten flux consisting of the fluoride of aluminum, together with the fluorides of a metal or metals more electro-positive than aluminum; the idea being to use a flux which dissolves the ore with the most facility, remains molten the longest, is least subject to decomposition, allows the best circulation around the anodes, and is the easiest to manage continuously without caking up.

Hérault suggested—and in his patents only mentions—cryolite, a specific mineral, composed of aluminum fluoride, 40·25 per cent.; sodium fluoride, 59·75 per cent. Hall preferred, and in his patents, besides his broad claim, suggests, several mixtures containing much larger proportions of aluminum fluoride, with the additions of the fluorides of other electro-positive metals,

notably the fluoride of calcium, as giving better results than with the use of cryolite alone as a flux.

The Pittsburgh Reduction Company, in its experience, has found some of these mixtures to give not only a greater yield per unit of electrical current, but a considerably less cost in operating, due to the freedom from caking from the products of the decomposition of the bath; and, more important still, has found that these special mixtures of the electrolyte have produced metal much freer from the impurities of sodium, carbon and occluded gases than it would be possible to obtain with cryolite alone used as the flux. The examination for these impurities (by the French chemist, Moissan), of the metal made in Europe, in comparison with that made by the Pittsburgh Reduction Company, has confirmed this fact.

Bauxite has become recognized as the best native ore of aluminum, and, as the purification of its contained alumina from silica, oxide of iron and titanic acid has shown that the silica is the *bête noir* of the operation, the location of bauxites rich in alumina, and at the same time low in contained silica, is an important factor to the manufacturer of aluminum. So far, the red bauxite of the Department of Var, in Southern France, has been the great and, in fact, the only large commercial source of such ore in Europe. The Styrian Alps have furnished some bauxite low in silica, and late reports have been that there had been some large deposits of such ore recently opened up; but it is a fact that, up to the year 1896, no large commercial shipments of it have been made, and that the operators in Southern France have furnished, from the district of the Var, practically all of the bauxite ore used in the manufacture of aluminum in Europe, with the exception of some few shipments of bauxite from America. The bauxites low in silica, in the Var in France and in similar large deposits in America, are all at the surface, with no superincumbent strata, except a few feet of surface earth and clay, to be stripped, and the mining is all of an open quarrying operation upon faces of the ore from 20 to 50 feet in thickness.

The British Aluminium Company, Limited, is now building a works at Foyers Falls, in Scotland, to manufacture aluminum. The water is taken from the river-bed, about ¼ mile above the falls, and is carried through a circular, brick-lined tunnel, 9 feet in diameter, to the slope of a hill, at the base of which, toward Loch Ness, the power-house of the proposed works is situated. The water is to be conveyed from the tunnel to a basin, from which five lines of cast-iron pipe (28½ inches internal diameter) convey it down the slope of the hill to the power-house, 45 feet wide, 90 feet long and 26 feet high, on posts, where each pipe is to feed a turbine water-wheel at the very considerable head of about 325 feet. This plant is estimated to have a maximum of about 4,000 horse-power when the high-water level in the tunnel can be maintained. The British Aluminium Company, Limited, has purchased the water rights to a very large tract of land in the hills above its present source of supply, and purposes increasing the natural drainage basin of its watershed and increasing the capacity of the locks which form its storage reservoirs. The British Aluminium Company, Limited, up to this writing (February, 1896), has not manufactured any aluminum, but

has acted as British selling agents for the Aluminium-Industrie-Actien-Gesellschaft, whose patents for the manufacture of aluminum in Great Britain, as well as those of the Cowles Company, it has bought. This plant and another at Sarpsfos, in Norway, are the only new ones now in actual progress of erection for the manufacture of aluminum that are known to the public at this time.

ELECTROLYTIC COPPER REFINING.

The annual report of the Anaconda copper mine, just presented, is very interesting, from the fact that electrolysis plays so large a part in the work. This Montana property has exceeded 100,000,000 pounds of copper per year, while the great Calumet and Hecla mine in the Lake Superior region shows up with but 90,000,000. On total receipts of $17,000,000, the Anaconda property shows a profit balance for the year of about $4,250,000, and is paying 10 per cent. on its present capital of $30,000,000. It appears that the refining plant can take care of 6,000,000 pounds of copper per month or 3,000 tons. On a basis of 200 tons of refined copper per day, the copper would yield 350,000 ounces of silver per month and 1,500 ounces of gold; and it is noteworthy that the Anaconda property, in addition to its 107,000,000 pounds of copper, is given credit in the report for 5,308,955 ounces of silver and 18,300 ounces of gold, which would represent about $3,500,000.—*Eng. & Min'g Jour.*

PRESENT CONDITION OF THE POWER UTILIZATION OF NIAGARA.

Mr. W. B. Rankine, secretary to the Niagara Power Company, contributes an interesting paper to the *Electrical Engineer*, from which we glean the following abstract:

The plans of the Cataract Construction Company and the works of the Niagara Falls Power Company are so far completed that delivery of power to customers in Buffalo has been successfully instituted, and the calls for power under contracts actually executed (and in excess of the present capacity of the works) will provide annual rentals which, with contracts in negotiation, represent a total income from that source falling not far below half a million dollars.

The present electrical installation comprises three dynamos, each of 5,000 electrical horse-power, of which one should be kept as a reserve; but the demand has made such reservation impossible, and the contracts already made for 15,825 electrical horse-power exceed not only the prudent, but the actual capacity of these works, which require immediate extension, with every prospect of prompt and profitable employment.

The proposed extension involves doubling the present capacity of the transmission line to Buffalo, which, already in successful operation, is delivering 1,000 electrical horse-power; the extension of the wheel-pit for its full length, so as to have capacity in all for ten 5,000 horse-power turbines and

dynamos; the installation of seven 5,000 horse-power turbines and dynamos, in addition to the three now in operation; and the extension of the power-house to cover the new installation. The work of such an extension of the wheel-pit is about one-third completed; the right of way from Niagara Falls to Buffalo is complete; the pole line already erected has a pole and cross-arm capacity for 20,000 electrical horse-power, with copper conductors in place for 5,000 electrical horse-power. Upon definite proposals already received, the entire installation above described can be accomplished within the year 1897.

As a concrete presentation of the facts, I will add a list of the contracts for power up to election day, 1896. No more eloquent statement as to results achieved could be given, were I to fill a volume of your journal:

	Horse-Power.
HYDRAULIC POWER.	
Niagara Falls Paper Company	7,200
ELECTRIC POWER.	
Pittsburgh Reduction Company (aluminum)	3,050
The Carborundum Company (carborundum)	1,000
Acetylene Light, Heat and Power Company (calcium carbide)	1,075
Buffalo and Niagara Falls Electric Light and Power Company (local lighting)	500
Walton Ferguson (chlorate of potash)	500
Niagara Electro-Chemical Company (peroxide of sodium)	400
Buffalo and Niagara Falls Electric Railway (local railway)	250
Niagara Falls and South Buffalo Railway Company (local railway) (All from October 1, 1896.)	250
Buffalo Street Railway Company (22-mile transmission) (From November 15, 1896.)	1,000
Acetylene Light, Heat and Power Company.	
(From February 1, 1897)	1,000
(From March 1, 1897)	1,000
(From delivery, say, November 1, 1897)	2,000
Mathieson Alkali Works (soda ash)	
(From June 1, 1897)	2,000
Buffalo Street Railway Company	1,000
Buffalo General Electric Company (lighting) (From November 15, 1897.)	3,000
Totals	25,225
SUMMARY.	
Total hydraulic power sold—Niagara	7,200
Total electric power sold—Niagara	13,025
Total electric power sold—Buffalo	5,000
	25,225
ADDITIONAL.	
Albright & Wilson, Limited (electro-chemicals)	400
1896—Grand total	25,625

It will be obvious at a glance that Niagara has already started on its career as a great chemical center, and thus justifies the predictions that the chemical trades would center ultimately around the sources of cheap power.

THE STORAGE BATTERY IN EUROPE.

American street railway companies cannot, as a rule, be accused of want of enterprise, and they have spent large sums of money in experimenting, or what is practically experimenting, on new systems of traction—mostly electrical. Just now, however, in the matter of the storage battery, they are letting others do the experimenting, and are watching carefully the outcome of the activity which is going on in the installation of accumulator cars in Europe. In Hanover, where a combination system of trolley and accumulators is employed, sixty cars have been equipped with batteries and eighty more are to be installed by next spring. The batteries are charged from the trolley line outside the city limits sufficiently to carry the cars without the aid of the trolley within those limits. In Dresden thirty storage battery cars are running and fifteen more are to be put on shortly. Here, also, the cars are run by the trolley outside, and by storage battery inside the city. In Copenhagen eighteen accumulator cars are to be in operation in the beginning of January. The system employed will be entirely storage battery. In Hagen, eight cars on the same system are in operation, and ten more are to be added. In Paris, thirty-five storage battery cars are to be equipped on the lines of the Compagnie du Nord. In Berlin the city government has decided to run on all the lines of the city storage battery cars on the mixed system, the outer lines to be equipped with trolley. The underground conduit has been entirely abandoned, and it is expected that Berlin will soon have in operation from 600 to 700 cars actuated by storage batteries.

CARBORUNDUM PRODUCTION AND USE.

The Carborundum Company reports to the *Engineering and Mining Journal* that its works have produced during the year 1896, in round numbers, 1,191,000 pounds or 595½ tons of crystalline carborundum. Consideration at the present is given to the production in crystalline form only, but another important industry into which carbide of silicon promises to be a valuable adjunct will naturally increase the usefulness of the material. Some mention has been made of the experiments showing that carborundum can be used, and will, in all probability, take the place of ferro-silicon in the manufacture of steel. Professor Luehrmann, of Germany, recently wrote an article on this subject, indicating that in the use of carborundum there will be in Germany alone, approximately, 2,500 tons consumed annually, provided its cost would not exceed 6 cents per pound. It may be used for this purpose in an amorphous form, and the Carborundum Company is prepared to furnish it at a price slightly under this figure.

Elsewhere in the *Journal* will be found an excellent descriptive paper on the carborundum plant at Niagara Falls, from the pen of Mr. Fitzgerald, chemical engineer of the works.

This industry stands as a conspicuous illustration of the possibilities of the electric furnace as the source of hitherto unknown and valuable products.

W.

BOOK NOTICES.

The Manufacture and Properties of Structural Steel. By Harry Huse Campbell, S.B. New York and London: The Scientific Publishing Company. 1896. 8vo, pp. 397. Price, $4

The above work adds another to the series of admirable metallurgical treatises that have emanated from the press of these publishers.

The author's long experience in the manufacture of steel, as the superintendent of one of the largest steel companies in the United States, and his practical familiarity with the various processes and machinery of the modern steel-maker's art, qualify him unusually well to treat the subject in such a manner as to command the respectful attention of metallurgical engineers.

Although confined, by its title, to structural steel, the author takes into consideration other branches of the steel industry that are closely related to it.

An interesting and valuable portion of the book is that which treats of the subject of establishing a standard for the strength of pure iron, and for the value of each unit of accessory constituents in modifying the strength in the commercial products known as steel, with the object of placing at the command of the steel-maker and steel-user a set of formulæ from which the composition of a metal designed for any special purpose can be computed, or *vice versa*.

The author's investigations on this most important subject are interesting, and his critical remarks on the work of others, notably on the work of Mr. Wm. R. Webster, may be read with instruction by all who wish to keep abreast of the present state of steel metallurgy. The author's comments on this topic will not be encouraging to those who have been hoping that a reliable working formula for representing and determining the strengths of steels would soon be at the command of the maker and user of the products known by this name. Intelligent criticism, however, cannot fail to be beneficial in eliminating errors and exposing the weak points of promising hypotheses. W.

The Influence of Sea Water on Hydraulic Mortars. Translated from the German of Herr Rud. Dykerhoff, by O. M. Carter, Captain Corps of Engineers U. S. A. Washington: Government Print. 1896.

This pamphlet contains the results of a series of experiments undertaken by Herr R. Dykerhoff, proprietor of extensive cement works, for the purpose of comparing native hydraulic limes and Portland cements with hydraulic lime of Theil and Santorin earth when exposed to the action of sea water.

The details of these experimental tests are given *in extenso*, and the results obtained are believed to contain information not to be obtained elsewhere. The translation is made specially for the information of the officers of the Corps of Engineers, but its value will be duly appreciated by engineers in general. W.

Resolutions of the Conventions held at Munich, Dresden, Berlin and Vienna, for the purpose of adopting uniform methods for testing construction materials with regard to their mechanical properties. By J. Bauschinger, Professor in the Technical High School, Munich. Translated by O. M. Carter, Captain Corps of Engineers, U. S. A., and E. A. Gieseler, U. S. Assistant Engineer. Washington: Government Print. 1896.

On Tests of Construction Materials. Translations from the French and from the German, by the same. Washington: Government Print. 1896.

These pamphlets, which have been printed primarily for the use of the officers of the Corps of Engineers, will prove of substantial value to the engineering profession at large, as a contribution to the important desideratum of securing uniformity in the methods of testing materials used in construction.

W.

Friction, Lubrication and the Lubricants in Horology. By Wm. T. Lewis, President Philadelphia Horological Society. (Illustrated.) Chicago: Geo. K. Hazlitt & Co. 1896.

The author of this little treatise calls attention in his introductory remarks to the fact that, while elaborate scientific treatises have been written on the mechanical branches of the watchmaker's art, comparatively little attention has been bestowed upon the subject—equally important in its relation to the accurate time-keeping qualities of the mechanism—of the lubrication of the watch or chronometer.

The study of this branch of the art reveals to the uninitiated a highly specialized industry, dealing with a comparatively small number of oils, of which a large proportion are of curious origin.

Mr. Lewis describes and treats of the properties of these products from the standpoint of the watchmaker, in a thoroughly satisfactory way. He describes the methods of testing oils, and gives an account of a number of experiments, undertaken by himself, to determine the relative value of the lubricants used in horology. The work should prove extremely useful to the practical watchmaker.

W.

Lessons in Practical Electricity, specially arranged for the use of students of the Electrical Classes at the Spring Garden Institute. By C. Walton Swoope, Instructor in Electrical Engineering. Philadelphia: The Spring Garden Institute. 1896.

This manual has been prepared by the author as a guide for the students in the Electrical Classes of the Spring Garden Institute under the author's direction. It appears, from a careful examination of its scope and character, to be exceedingly well adapted for service in a graded course of instruction for beginners; in fact, we know of no work in the English that is so well suited for the needs of beginners. The method of the work is strictly experimental, and practical exercises, in the form of problems for solution, accompany the text wherever the subject renders them admissible.

W.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, January 20, 1897.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 20, 1897.

JOSEPH M. WILSON, President, in the chair.

Present, 118 members and visitors.

Additions to membership since last report, 11.

The Actuary reported the following resolutions passed by the Board of Managers, at its stated meeting, held January 13, 1897.

"*Resolved*, That the President and Secretary of the Franklin Institute be and are hereby authorized to take immediate steps to secure subscriptions to a guarantee fund of at least $25,000, to protect the Institute against pecuniary loss in connection with the holding of an exhibition devoted to the textile industries.

"*Resolved*, That as soon as the minimum amount above-named shall have been subscribed, the Board of Managers shall proceed to make public announcement of the fact that the Institute will hold, in the autumn of 1897, an exhibition devoted to the textile industries, including therein the raw materials, processes, machinery, and the products, and the arts of design in connection with the textile industry, and take immediate steps to carry the undertaking into effect, provided a lease of the building can be obtained on satisfactory terms."

The Secretary submitted the annual reports of the Board of Managers, the several Standing Committees and Sections of the Institute, and the Trustees of the Elliott Cresson Medal Fund, which, on motion, were accepted.

(The annual report of the Board is printed elsewhere in this impression of the *Journal*.)

The judges of the annual election presented their report, whereupon the the President declared the following persons to be elected:

*President**	to serve one year, ...	JOHN BIRKINBINE.
Vice-President	" three years, ...	W. P. TATHAM.
Secretary	" one year, ...	WM. H. WAHL.
Treasurer	" " "	SAMUEL SARTAIN.
Auditors	" three years, ...	W. O. GRIGGS.
	To serve for the unexpired term of Samuel H. Needles, deceased . .	JOHN H. COOPER.

* Mr. Joseph M. Wilson declined a renomination.

Managers (to serve three years).

ARTHUR BEARDSLEY,	F. L. GARRISON,
HENRY C. BROLASKY,	H. W. JAYNE,
JAMES CHRISTIE,	LAWRENCE T. PAUL,

HORACE PETTIT.

Committee on Science and the Arts (to serve three years).

WM. M. BARR,	JOHN HAUG,	LOUIS E. LEVY,
H. F. COLVIN,	WM. C. HEAD,	D. ANSON PARTRIDGE,
THOS. P. CONARD,	WM. C. HENDERSON,	TINIUS OLSEN,
SPENCER FULLERTON,	H. R. HEYL,	SAMUEL P. SADTLER,
JOHN M. HARTMAN,	GEO. A. HOADLEY,	PAUL A. WINAND.

The judges of the election were given a vote of thanks for their services.

On motion of Prof. F. L. Garrison, duly seconded, the meeting, by unanimous vote, adopted the following resolution:

"*Resolved*, That the grateful thanks of the Franklin Institute be and are hereby tendered to its retiring President, Mr. Joseph M. Wilson, in recognition of his faithful attendance as presiding officer at the stated meetings during the ten years of his service as President, for his uniform courtesy and impartiality as a presiding officer, and for his constant and unremitting efforts during this period to further the movement for a new building and to promote the usefulness of the Institute."

The retiring president made an appropriate response in acknowledgment.

A vacancy in the Board of Managers, reported by the Secretary, was filled by the election of Mr. Otto C. Wolf.

Prof. Angelo Heilprin, delegate of the Institute to the Millennial Celebration of the Kingdom of Hungary, gave an oral account of his mission, under the title of "Observations on the Progress of a Nation—Hungary." The speaker's remarks were devoted largely to the municipal improvements exhibited in the city of Buda Pesth, and the engineering improvements of the mouth of the Danube.

The meeting passed a vote of thanks to Prof. Heilprin for his interesting and valuable report.

Mr. A. E. Outerbridge, Jr., made some remarks on the subject of "The Advantages of Mechanical Stoking," with especial reference to the conditions involved in the abatement of the smoke nuisance in cities. The subject was illustrated with the aid of lantern slides showing such devices in operation. Extended references were also made to the substantial reforms that had been realized in Chicago and other cities where soft coal is almost exclusively used, by the adoption of municipal ordinances regulating the operation of steam plants.

Mr. H. C. B. Nitze described and exhibited in operation an improved "Magnetic Ore Separator," devised by Mr. J. Price Wetherill, of Bethlehem, Pa.

Mr. H. R. Heyl exhibited and described an improved safety device for bicycles.

Adjourned.

WM. H. WAHL, *Secretary*